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The primary objective of this project was to carry out a Producibility, Engineering, and Planning (PEP) analysis of production systems for the manufacture of Tray Pack foods for Military field feeding use. Existing production capacities of Tray Pack foods, current manufacturing processes, and automated equipment and technologies have been examined in this PEP analysis in order to evaluate the ways and means of meeting Tray Pack demand.

The report documents the on-site visits, observations, and subsequent analysis of the PEP teams' visit to six producers of Tray Pack foods. In essence, the report documents a number of deficiences in the system for manufacturing technologies and operations currently employed by producers. Problems, issues and recommendations center on engineering and planning, engineering design, and engineering control of Tray Pack foods. It was concluded that unless action is taken to improve manufacturing technologies and operations, desired production volumes for Tray Packs will not likely be achieved.

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PREFACE

This report is a Producibility, Engineering and Planning (PEP) analysis initiated to identify Tray Pack manufacturing problems and determine feasible alternative ways and means for resolving these Tray Pack manufacturing problems.

The University of Massachusetts Departments of Industrial Engineering and Operations Research together with the Department of Food Engineering were hired by the U.S. Army Natick Research, Development and Engineering Center to perform this PEP analysis under Project No. 1L162724AH99. Project Officer for Natick was Mr. Joseph Szczeblowski.

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PRODUCIBILITY, ENGINEERING, AND PLANNING FOR TRAY PACK FOODS

CHAPTER I

PEP Introduction

A. Overview

The primary objective of the Producibility, Engineering and Planning (PEP) report is to analyze production system problems and develop solutions for the manufacturing and assembly of Tray Pack foods for Military field feeding use. Within the scope of this engineering analysis and design, the mission has been to examine existing production capacities of producers of Tray Pack foods, to evaluate current manufacturing processes and automation equipment, and to develop recommendations regarding manufacturing technology and systems so that Tray Pack foods can be produced to meet projected demands over time.

B. Project Objectives

The effort entailed the following specific objectives:

- Identify potential Tray Pack manufacturing problem areas relative to their producibility
- Examine producer's plant capacity (size of plant, equipment, labor force) in order to meet potential demand for Tray Packs over the planning horizon.
- Examine current production line layouts, material handling equipment, labor and work station design problems.
- Make recommendations with regards to the potential resolution of the above producibility problems both at the systemwide and at the producer's level.

C. Project Assumptions

1. Tray Pack Demand

A specified yearly demand for Tray Packs was not assumed, although as brought to bear throughout the study, the demand figure is crucial to producibility. In terms of its impact on producibility, a software product described in Chapter III was developed to measure the impact of demand on producibility.

2. Can Design

It was assumed that the can's present 105-fl-oz design which is manufactured out of steel with an enamel coating and is dimensionally 10 inches wide by 12 inches long by 2 inches deep, 1001 x 1206 x 200 in can makers' terminology, was the vehicle for containing the menu items. The team did not pursue alternative design changes other than to point out possible alterations to the can which might improve producibility.

3. Ten-day Menu Cycle

Current plans require a ten-day menu cycle with 44 regular menu items broken down into four menu groupings: entrees, starches, vegetables, and desserts. In addition, there are 29 alternate menu items which could also be produced. In Chapter III and Appendix A, the 44 regular and 29 alternate menu items are discussed.

4. Multiple Producers

Production of Tray Packs appears to be headed towards a decentralized system. This appears to be a trend in the military which creates efficiencies as well as inefficiencies and potentially has a major impact on producibility. Certain features, problems, and potential ideas surrounding this decentralization are noted throughout the report.

5. Automation

The state of the art in manufacturing technology for Tray Packs was examined with the idea of achieving a maximum of 25 to 50 cans per minute for all 44 regular and 29 alternate menu items. This range of output rate was a critical assumption in evaluating the producer's capacity and ability to achieve this goal.

6. Production Costs

Production costs for the various menu items were not directly tabulated by this team. However, those aspects of producibility which indirectly affect production costs were examined, namely: product specifications, product demand, automation innovations, flexibility in assembly techniques, and general operational analysis.

D. Project Methodology

1. U/Mass Project Team

The project team responsible for the PEP research was comprised of two members from the Food Engineering Department and two members from the Industrial Engineering and Operations Research Department of the University of Massachusetts campus in Amherst, Massachusetts. All members of the team were under the supervision and direction of Joe Szczeblowski, Physical Scientist of U.S. Army Natick Research, Development and Engineering Center (Natick).

2. Site Visits

The project team visited six of the seven producers of Tray Packs on a fact finding mission to document problems of producibility, learn of new innovations in the assembly and automation of items in the cans, and generally observe and listen to producers' experience with manufacturing

Tray Packs. This empirical work was carried out over a three-month period in the summer of 1984.

In addition to the site visits, particular software items were developed to assess the producer's ability to meet projected line rates and yearly Tray Pack volumes. Also a computer simulation tool was developed to assess production rates, congestion, and overall line reliability in the face of machine breakdowns and other problems. These software tools are discussed in Chapters III and IV of this report.

E. Summary of Results

The overall approach to this PEP project could be considered as a feasibility study to examine the capacity of current producers to manufacture Tray Packs achieving a maximum of 25 to 30 cans per minute on all menu items. The overall conclusion at the present is that this is currently not feasible and that production rates will remain below 20 cans per minute for most items and some will remain below 10 cans per minute unless suitable automation of the lines is introduced. With the current seven producers, 6 to 10 million trays per year can be realized which is well below the desired output of 25 to 30 cans per minute.

Changes in Tray Pack production line technology and the assembly operations of the cans are necessary, such as in the design of specialized conveyors, lid crimping and/or clipping, improved seamer technology, and possibly the can design itself. These specified problems are mentioned throughout the report and detailed recommendations regarding these improvements are recorded in Chapter VI.

This pessimistic conclusion specified above is not irresolvable but one that deserves specialized research and planning in the design and control of these production lines if production line rates of 25 to 30 cans per minute are to be fully realized.

CHAPTER II

Problems and Issues

A. Background

The Tray Pack concept of food packaging, processing, handling and serving originated well over a decade ago principally from Natick and was commercially first introduced by Central States Can Company and Kraftco circa 1972.

Both the food industry and the military quickly saw the potential quality improvements to be derived from a "can" having the configuration of a half-sized steam table tray, rather than the cylindrical shape of the No. 10 can.

Since the introduction of the Tray Pack concept, both Natick and the food industry have devoted considerable time and money to research and development aimed at exploiting the concept of producing a wide range of canned foods that are shelf-stable, of unusually high sensory and nutritional quality, that need only to be reheated within the container before serving, and that can be served directly from the container.

In 1981, a report entitled a "Proposed Combat Food System Concept for the Army in 1990" was released by Natick.[1] In this proposal, it was stated that "The T ration is the basic building block of the new Combat Food System . . . ."

In 1981, the Army Training and Doctrine Command prepared a requirements document that identified the need to develop a new Combat Field Feeding System (CFFS) which included a T ration (together with the MRE (Meal, Ready-to-Eat) and the B ration).[2]

A Force Development Testing and Experimentation (FDTE) evaluation of the CFFS was conducted at Fort Hood, TX from 13 October to 10 November 1982. One of the conclusions drawn from that evaluation was that "the T ration system is outstanding."[3] Acceptability by soldiers was good and the damage rate to containers was less than 1% (104 out of 11,060).

Service acceptance tests on nineteen Tray Pack items were performed at Eglin AFB, FL during 17 to 23 January 1984 and with Marine Corps and Army troops at Fort Bragg, NC between 12 and 26 March 1984.[4] The second series of Service acceptance tests of the remaining twenty Tray Pack production items were performed at Eglin AFB, FL, 13 to 20 September 1984, and with the Marine Corps and Army Troops at Ft. Bragg, NC, 18 to 21 September 1984 and 22 to 26 October 1984, respectively.[5] Similarly, acceptance testing of the alternate Tray Pack products will be planned as soon as their production tests are completed. Following successful acceptance testing and final approval by AFPEC (Armed Forces Product Evaluation Committee), Tray Pack foods comprising the basic menu will be introduced in the supply system. It is expected that the alternate Tray Pack products will become available by the same process in FY86.

B. PBP System Overview

As an overview of the Tray Pack system for production, it is useful to examine the current configuration of producers. These producers are listed below in the order visited:

1. Vantage Foods, Cincinnati, Ohio
2. Bryan Foods, West Point, Mississippi
3. Vanee Foods, Berkeley, Illinois
4. Shelf Stable Foods, Evansville, Indiana
5. SoPakCo Foods, Bennettsville, South Carolina
6. Sterling Bakery, San Antonio Texas

The only facility not visited was Freedom Industries, Inc. Bronx, New York.

Figure 1 illustrates the geographic location and dispersion of the producers. While the producers remain somewhat independent, their operations are dependent on raw material distribution, can and lid acquisition (Central States Can Company), and shipping concerns arrangements between one another.

A main objective in visiting the producers was to gather information regarding producibility problems and issues and observe any innovations the producers may have regarding engineering design and control of the Tray Pack lines.

C. Producibility: Issues and Problems

Producibility Engineering and Planning (PEP) is an engineering effort that provides "software" technical data packages (TDPs) that will improve timeliness and cost effectiveness in producing essential material within the target unit cost constraints. The purpose of PEP is to ensure the reliable producibility of a developed end-item or component prior to release for production. It involves engineering tasks undertaken to ensure a timely and economic transition from development.

1. **Manufacturer's Overall Expertise**. The manufacturer's overall level of expertise and reliability includes his skill in organizing and carrying out good food manufacturing practices, his access to continuous scientific/technical backup required to evaluate and update ongoing manufacturing, his ability to identify and develop improvements in the processes used to produce new or novel products, and, finally, his skill at assessing quality characteristics and public health related factors at appropriate stages during manufacture.

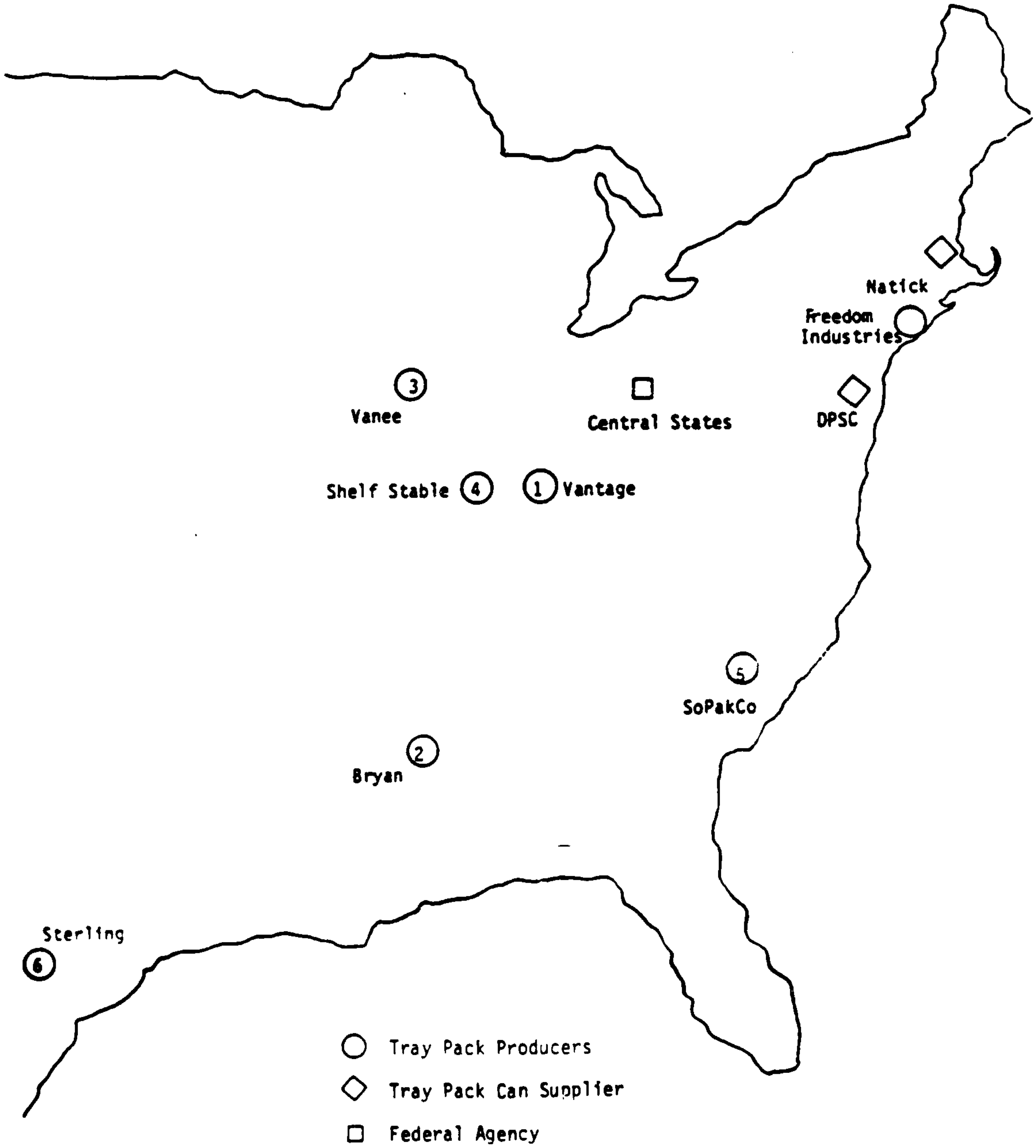

Figure 1. Geographic location of producers.

Present Tray Pack producers are, with few exceptions, small or medium-size companies that exist to serve other commercial buyers (copackers) and to serve as government contractors. None of the producers has designed a production line for Tray Packs because of relatively small contracts and the uncertainty of future contracts. Most producers have simply used what they had and added only a minimum of additional equipment usually a Tray Pack seamer. The primary objective has been to produce an acceptable product, rather than production efficiency.

The type of companies producing Tray Packs are among those who usually have little engineering capability in-house. Mostly they have relied on intuition and ingenuity resulting from long practice and have been shielded by the slow evolutionary changes that have taken place in the old, more conservative segments of the food industry. When a new technology has been introduced (always piecemeal), such producers have relied largely on vendors of equipment and suppliers to do their engineering for them. This traditional practice is, of course, not possible in Tray Pack production. Thus, engineering systems do not exist and are not likely to be developed in the present climate. Instead, the tendency is to increase production by using present equipment, a larger number of hours, or to install multiple production lines of substantially the same type.

2. **Specifications and Communication**. Specifications are intended to assure a level and consistency of all important product attributes. Skillfully drawn specifications must take into account the availability in the usual market channels of the ingredients - and forms of ingredients - specified, as well as the reasonably available equipment and methods necessary for preprocessing, processing, and post-processing operations, including cartoning and shipment to the customer's site. Unrealistic or unachievable specifications tend to reduce the number of bidders and increase costs. On the other hand, carefully drawn realistic specifications can be made to assure quality and consistency of quality without unnecessarily restricting the possibilities for useful give-and-take interaction between manufacturers and those preparing or enforcing the specifications. Clearly, specifications,

even preliminary ones, should not prohibit nor strongly discourage manufacturers from proposing "different and better" or even "different but equal" alternatives for achieving the central purpose of specifications. Instead, manufacturers should be encouraged to make known to the government possible changes or modifications in any specification which fails to recognize or take advantage of manufacturing realities related to least-cost production without significant deleterious effects to the products during production or at any subsequent time during the anticipated transport, handling, and storage period.

Most Tray Pack producers we visited had complaints about the limiting effect of detailed regulation-type specifications. Most believed that better, more effective communication regarding specifications, amendments to specifications, and waivers would/could lead to improved products and/or lower costs. In one instance a production manager stated that the adoption of performance-type specifications would lead to a 20% reduction in the cost of Tray Packs produced by his company.

This issue is one of long standing and probably it is not realistic to expect permanent resolution. Some mechanisms already exist for encouraging dialogue and interaction between military food procurers and the manufacturers of the products. These mechanisms should be better defined and used more extensively.

3. Production Volume. To make major reductions in the Tray Pack production costs, it is necessary to increase volume. The prospects of large volume contracts should help to encourage manufacturers to invest the funds necessary to secure the best, most productive, most reliable equipment and to develop and/or adopt the best current manufacturing methods to achieve high quality products at competitive costs. This prospect would also bring more manufacturers into the competitive bidding process, thus encouraging further commitment to improvements in all aspects of manufacturing operations.

During visits to Tray Pack producers, low volume production was cited as the greatest deterrent to more efficient production. Most producers said

they could produce X times as many Tray Packs as they were presently producing. Although there was some belief expressed that large volume would result in "more experience" and experience would lead to greater efficiency, it was often said that the same procedures used every day, rather than one day per week would lead to greater efficiency. It was more often said that the same procedures used every day, rather than one day per week would lead to a fivefold increase in production. A proposed method to double or triple production was simply to set up two or three identical production lines. Another "solution" suggested was that second shifts could be instituted if volume requirements demanded it. Of course, a second shift probably would greatly influence efficiency. More complete use of high cost equipment and longer use of high overhead cost facilities are the only persuasive parts of these arguments. We heard of no plans by present producers of Tray Packs to undertake any production-efficiency campaign under present or short-term or even intermediate-term circumstances.

Most producers have dedicated little or no space to production lines for Tray Packs. The usual practice was to set up a temporary Tray Pack line using general purpose apparatus (conveyors, tables, etc.) mostly, with the addition of one (a seamer usually) or only a few pieces of equipment brought from temporary storage. A large proportion of product handling, Tray Pack filling, weighing, etc. was done manually. A typical line for 6 to 8 Tray Packs per minute required 8 to 12 people. Occasionally the Tray Pack line was quite similar to the commercial canning line, with the exception of the seamer.

Planning for complete utilization of a production line to produce the maximum number of Tray Packs at the least manufacturing cost did not appear to be an active interest of any of the producers we visited. It doesn't appear that this situation will change until contracts are much larger (500,000 units per year, for not more than 6 or 7 recipes according to a manager at Shelf-Stable Foods), and the acquisition program is more predictable.

Most producers have not achieved, probably have not seriously tried to achieve, a balanced production line where each component is used effectively and efficiently and in which the whole functions as a system. Most lines had serious rate deficiencies attributable to one or more components. Sometimes seamer rate was the deficiency; for others, retort capacity (and/or availability) was deficient; and for most, filling, weighing, and movement from point to point on the production line were bottlenecks; for some, packaging was a problem. For most producers, efficient labor (manpower) utilization was not achieved.

4. Container Design. Although much work has already been done toward the development of a suitable container, the present container has some deficiencies. Damage during shipment and handling was noted by at least one Tray Pack producer. Distortion of the containers has been noted by others, including Natick personnel. An improvement program is underway, and it is expected that it will lead to a further improved container, resistant to both handling and processing stresses.

A deficiency in Tray Pack handling during production that may be partially overcome by container modification is the excessive "slopping over" when Tray Packs filled with low viscosity fluids are accelerated, even at very modest rates. This is troublesome whenever it occurs since sometimes it requires redoing some part of the operation in a slow, manual way.

Market uncertainty (presumably) has resulted in production of Tray Pack containers by only one company. Although this company may have the capacity to supply all of the Tray Packs required by the military for the short term, the situation is an unfavorable (unacceptable) one for the long term. Container cost may be related to the number of producers, and in the extreme rapid increases in quantity may be difficult. (Labor unrest, major and unpredictable accidents, such as fire, explosions, can cause unplanned delays).

5. Equipment. Processing machinery designed/manufactured specifically for Tray Pack production has been limited to seamers. Seamers from three manufacturers (Yaguchi, Callahan, and FMC) are being used by present

producers of Tray Packs. The Yaguchi seamer is the only one of the three that did not require manual assistance.

Yaguchi, a Japanese manufacturer, seems to be the only producer of seamers with a commitment to continued production of seamers, with significant improvement from one generation to the next. The FMC seamer is slow, inefficient and appears not to be an important factor in production improvement Callahan Ams Machine Co. was until recently an active producer of Tray Pack seamers with a commitment to improvements in capability. Their machines ranged from manual to automatic operation. Recently the Callahan Ams Co. was acquired by Rollasen Engineering. Whether they will remain active in Tray Pack seamer development and production is an unanswered question. It may be that seamers, like containers, will be produced by only one company, with the added difficulty of having that producer located in Japan.

Fillers made especially for Tray Packs do not yet exist. Filling is done manually or by manual assist methods. Modifications of present can fillers or the development of new fillers for Tray Packs is needed.

It is only in the retort area that we found adequate equipment being produced under stable conditions by a number of manufacturers. Although old equipment, including many small, still retorts, continue to be used, the situation is not due to the unavailability of retorts of adequate capacity and function.

It is well established, of course, that Tray Pack configuration is favorable to increased rates of heat penetration and reduced cook times, when compared to #10 cans in similar retorting operations. Agitation of a cylindrical can with significant headspace greatly increases the rate of heat penetration. Whether the use of agitating retorts will result in substantial further reductions in cook times for Tray Packs is a vexing question for some Tray Pack processors. Basic considerations suggest that heat penetration rates for a container of zero, or near zero, head space

will be little affected by agitation, unless there is appreciable non-uniformity in local heat transfer coefficients over the various surfaces of the container. If, however, there is head space of 1/4 inch or so, which is maintained during retorting, agitation will likely have a pronounced effect on heat penetration rates and cook times.

6. Automation. It appears certain that batch processing will continue well into the future, so mechanization rather than automation is the best that can be hoped for in short to intermediate range. Automatic operation in certain steps of the process can be achieved (seaming, perhaps filling in some instances, retorting, check weighing and rejection of off-spec containers, are examples).

Automatically (computer) controlled, continuous production lines for Tray Packs are still in the realm of optimism. Only huge increases in demand could significantly alter this.

7. Manpower, Labor Issues. So long as manpower costs in certain localities are subsidized by government, the emphasis on improved efficiency will lag. Only when labor costs begin to catch up with the costs of mechanized (automated) methods will genuine interest in overall production efficiency be a truly important issue.

8. Commercialization. The very optimistic view of the potential of Tray Packs in commercial and nonmilitary institutional markets that prevailed at the time of concept introduction and for a short time after has now given way to a much less optimistic view. To further complicate commercialization forecasts, alternative and competitive containers and production methods have emerged and continue to emerge. There is such a major difference in military container requirements, as currently specified, and container needs for products for the civilian economy that cost differences are likely to remain large and military Tray Packs will have to be separated from civilian products tracing back to the same concepts.

D. Specific Problems and Issues

Our specific observations based upon these site visits are collected below into three major categories of issues for consideration: PEP Planning, PEP Design, and PEP Control. We present these findings for consideration because they have emerged as potential problems to producibility. We, at this stage, do not purport to have ready, simple answers to all these issues but feel they are necessary to be stated and further examined as we shall do so in the following Chapters.

PEP Engineering & Planning refers to the policy and program issues affecting the Tray Pack system as a whole, together with the interaction among producers, Natick, and Defense Personnel Support Center (DPSC). PEP Engineering Design refers to those issues concerning the physical design of the Tray Pack lines, their layout, material handling, equipment, and staffing. Finally, PEP Engineering Control refers to those policy, programming, and production issues that affect the operations of the Tray Pack lines themselves such as cost control, inventory control, and scheduling. In later chapters, final recommendations will be made in these areas to show how some of these issues might be resolved, but only after our discussion on Demand Analysis of the trays along with a detailed analysis and design of automation costs and related flow analysis of the Tray Pack lines.

1. PEP Engineering & Planning

a. Specifications

o From our on-site experiences, most all producers felt that improvements could be made in the product specifications so that lower costs and higher quality could be achieved. The statement, "Tell us what you want as the end product, and we'll figure out a way to do it," was consistently raised by most producers.

o What is flexibility in a performance specification? How much change and where should changes be made or allowed in the product specifications?

o Are there optimal retort times for each item?

b. **Quality Assurance**

o What ways or methods could be devised to make product testing more uniform and less costly to the producer?

c. **System Costs**

o Is reliance on Central States eventually to become a key bottleneck as production volume increases? What alternatives exist to create more flexibility in supplying the cans?

o Can centralized packaging be an effective tool for reducing packaging and shipping costs to the producers or will increased demand absorb these costs?

o What other types of centralization could be cost effective (printing of labels, raw material distributions, and so on) without losing the decentralized control each producer maintains?

d. **Communication**

o Would a frequently occurring informal seminar of producers, Natick, and DPSC be useful for sharing problems, ideas, innovations or would the producers hold back for fear of divulging trade secrets? How can communication be fostered for all involved?

e. **Raw Materials**

o It was learned from our visits that certain producers were able to supply their own raw materials, whereas others could not. This inability to provide raw materials restricted the production. Should certain producers be allowed to only produce meat items, starches and vegetables and others, desserts and cakes?

o Should the producers themselves resolve their raw material problems or is some sort of government intervention necessary? Is it simply a matter of product specification changes?

f. **R & D Incentives**

o Would R&D incentives to producers be the most effective way to handle technology transfer?

o How should University research activities aid in providing this technology transfer?

o Much of the equipment used in Tray Pack production is international, either Japanese or European. What maintainability problems will accrue over time? Especially with increased demand, automated equipment planning and maintenance will become a major factor in achieving maximum production output by the individual producers.

g. Demand Levels

o What is the breaking point in demand for large producers such as Bryan and SoPakCo so that their production costs are justifiable? One, two, or three million trays per year?

h. Commercialization

o Does a commercial market exist for Tray Packs? Can incentives to producers be created to enhance the image of Tray Packs so that they are more marketable?

i. Location and Number of Producers

o How many producers are needed as demand increases? With the increased volume and including the alternate items, additional producers not initially forseen may be required in order to satisfy demand.

o How many production lines are needed? Given the possibility of multiple products, certain producers will begin to become constrained for resources (equipment, staff, labor, and space). How are these resources and the number of production lines to be defined?

o Is there an "optimum" number of facilities and where should they be located so that distribution costs are minimized?

2. PEP Engineering Design

a. Equipment Automation

o Current technology limits the Yaguchi (the fastest seamer) to between 8 and 15 trays per minute. What alterations in the Yaguchi's lid/can marriage or seaming operation could increase speed to 30 per minute?

o Are their any changes in the can design which could improve line speeds?

o How should a crimping operation be carried out to minimize sloshing in the trays? Simply clipping the lid on the can? A magnetic clip?

b. **Labor**

o Presently production lines are comprised of mostly manual labor, since purchasing automated equipment cannot be justified if it will be underutilized and manual labor is available. As contract sizes increase and automation is required, labor will not decrease; however, it will be required to become more skilled and may cause initial concern to producers.

c. **Material Handling**

o How is sloshing to be controlled; by changes in can design; by specialized conveyors?

o Will parallel lines be the primary means of achieving larger production rates or will new automated feeding, lid placement and seaming machines need to be developed? Who should develop these technologies?

d. **Layout and Location**

o Which types of line configurations are most suitable for Tray Packs? How will these line configurations impact the rest of the plant and operations?

o Would some type of computerized layout design package be appropriate to aid producers in their line layouts?

e. **Line Balancing**

o When will the producers begin to assign tasks to work stations to balance the assembly lines? Do the producers have enough technical expertise to do so?

3. **PEP Engineering Control**

a. **Production Costs**

o Costs are a key factor in the commercialization and production of Tray Packs. Can computerized budgeting and accounting systems help the producers in trimming production costs? Only one producer had any real experience with computer controls; how can this technology transfer be enhanced?

o What type of computer resources (hardware and software). are appropriate for each producer as production volume increases?

b. **Lead Times and Inventory Control**

o Lead times will become more critical as volume increases. How can the producers optimize their orders for cans, lids and labels so that their production costs are minimized? Are there available software programs that could help the producers effectively manage their inventory control problems?

c. **Scheduling**

o Most producers are simultaneously producing commercial products along with Tray Packs. How can these multiple products be properly scheduled during their production runs so that resource utilization and product due dates can be optimized?

d. **Computer Control**

o Certain equipment items may eventually have computer controls mounted on them to aid in controlling cook times, pressures, and so on. Is there a way in which the producers can share in this technology transfer?

o Who should be responsible for disseminating this technology transfer?

Certainly, more empirical survey work could be carried out to refine existing line designs, facility requirements, and equipment needs of the producers as well as setting time standards for the tasks assigned to the work stations. This was well beyond the scope of the initial PEP site visits for the present study. In the next Chapter, the analysis of the demand for Tray Packs and a computer program that generates alternative scenarios for Tray Pack production demand and its resultant impact on producer capacity and demand requirements are presented. Specific recommendations to improve producibility will also appear in Chapters IV and V.

CHAPTER III

Production Demand Analysis

A. Introduction to NATPRO

To better address the issue of Tray Pack Producibility one must first understand the issue of Tray Pack demand and the interaction between producibility and demand. It would be beneficial if one could determine the number of trays consumed by a person during a Ten-Day Concept Tray Pack Menu including all of the 44 Basic Meal Plan Items. These (ten-day basic meal plan) constants could then be used to predict the consumption per person, in trays per menu item, for any predetermined multiple of (ten-day meal plan) cycles. Multiplying these totals by the number of persons to be fed by the Tray Pack System for an indicated time interval would give the requirements per menu item, for all menu items, resulting in the associated Tray Pack System demands. Eventually, one would have to apply to these menu item demands some factor (waste, damage, etc.) that would correct these requirements to give a more complete picture of demand over the time interval in question.

If such data are readily available, one could then simulate "what if" scenarios with the Tray Pack System. One might want to know what it would take to produce an inventory of Tray Packs capable of feeding two million persons for 3 cycles (30 days) given a lead time of one year to build up the inventory. Another worst case scenario might be, given 30 days lead time, what would it take to feed 2 million persons for an indefinite period of time?

If one can generate reliable consumption constants (per person, per cycle, per menu item per tray pack) then, allowing for worst case scenario conditions, one can address the Tray Pack producibility issue with confidence, since there is a direct relationship between the two. If there is a particular demand of Tray Packs per day, there must be a feasible system

existing or developed that can produce at this rate. By knowing what is required, the break points of feasible and nonfeasible Tray Pack production capabilities based on the various system and production line configurations can be estimated.

NATPRO (NATick PROducibility) a FORTRAN-77 Demand Analysis Program was developed to generate production demand figures, based on the number of persons to be fed per time interval or the number of Tray Packs to be produced per time interval, where one is a function of the other. Two forms of input are allowed since at various times one may want to know the number of persons to be fed and thus need to know how many Tray Packs of each menu item must be on hand to feed them, while at other times one may want to know the inventory capacity of a distribution center needing to be stocked.

With NATPRO, one should be able to determine the present Tray Pack System capability as far as how many persons could be fed. By recommending production line improvements and by increasing the number of lines in the Tray Pack System, different levels of Tray Pack production and thus persons to be fed can be determined.

If one knows the number of persons to be fed in a time interval, one can use NATPRO to determine the number of production lines that would be required to fulfill the demand.

B. NATPRO

NATPRO has been written to be user friendly and can be run with or without any user interaction. The demand parameters, either the number of persons to be fed and/or the number of trays to be produced, can be entered as internal data to the NATPRO program. Presently, five levels of each type of demand parameter can be set prior to running the program; however, this could easily be increased. The advantage of having the program run without user interaction is for hard copy output generation. Since the output is extensive, if one had several runs which needed to be printed out, waiting to complete each printout before being able to request another would take a

considerable amount of time. Therefore, by allowing the user to set the desired demand parameters, run the program, and write the output file, it saves the user significant time and allows the user to use this time to do other things while the output file is being printed out.

The advantage of having the program run interactively is that it allows the user to narrow in on the desired demand goal or generate "what if" scenarios with different demand parameters. By keeping a list of critical demand scenarios, the user can later enter those values in the demand parameter table of the non-interactive mode of the program and have the output printed for more intensive investigation and study. A description of the fundamental variables and constants in NATPRO occurs in Appendix A.

NATPRO is driven by a table of 114 constants. These constants are the number of trays per person, per ten-day cycle consumed of each of the 44 basic meal plan menu items, the 29 alternate menu items, and 41 item numbers not in use, grouped by food category. Seven parameters make up the identity as well as the mathematical value of each of these 114 constants.

Once the 114 constants are generated by the parameters and stored internally in the program, output can be generated. The parameter tables can be changed, added to or subtracted from and will not affect the NATPRO program as long as one follows the formatting criteria set up for each parameter. For example, a change would be necessary if new menu items are to be added to the system, or if a second ten-day meal plan is initiated, or such an occurrence would necessitate a parameter change.

As previously mentioned, NATPRO can be run interactively or by having the user hard code a list of demand constants into the program. Output from NATPRO is the same regardless of program mode.

C. NATPRO Output

For each run of NATPRO at least two tables of output are generated. The first table, the "Table of Constants", is generated once. The second table, the "Table of Production Demands", is generated for each demand variable entered during a run. All output in the "Table of Production Demands" is generated using the "Table of Constants".

1. Table of Constants

The table of constants is a structured display of the seven parameters used to represent the identity and mathematical values of the 73 active menu item constants and 41 item numbers not in use. The table is broken down into 5 sections as follows:

a. The Ten-day Basic Meal Plan Items
b. The Alternate Tray Pack Items
c. Item Numbers Presently Not in Use
d. The Ten-day Basic Meal Plan by Food Categories
e. The Alternate Tray Pack Items by Food Categories

The main use of this table is input for the generation of the Table of Production Demands. However, direct viewing of the "Table of Constants", in its present form, allows one significant insight into the state of the Tray Pack System. In Table 1 a viewer is given a sample section of the Table of Constants, for a more detailed overview, see Appendix A. One is able to easily view how each item is defined within the system and how each item within the system relates to every other item in the system. Also displayed are the summation of the two main groupings, the Basic Meal Plan Items and Alternate Tray Pack Items, as well as the subgroupings by the four Food Categories.

TABLE 1. Sample Data from the Table of Constants

Ten-day Basic Meal Plan Items

Item No.	Item Name	Portions per Cycle	Portions per Tray	Cycles per Year	Trays per Person per Cycle	Trays per Person per Year	Overall Item Percentage
	Entrees						
002	Beef stew	1.0	13.0	36.5	0.077	2.808	2.137
003	Beef in barbecue sauce	1.0	15.0	36.5	0.067	2.433	1.852
004	Beef pepper steaks	1.0	15.0	36.5	0.067	2.433	1.852
017	Turkey slices w/ gravy	1.0	18.0	36.5	0.056	2.028	1.543
021	Ham slices	1.0	18.0	36.5	0.056	2.028	1.543
028	Frankfurters in brine	1.0	22.0	36.5	0.045	1.659	1.263
035	Meatloaf, mshrm gravy	1.0	20.0	36.5	0.050	1.825	1.389
042	Canadian bacon	3.0	18.0	36.5	0.167	6.083	4.629
058	Beef, ground, creamed	2.0	15.0	36.5	0.133	4.867	3.704
062	Pork sausage links	3.0	30.0	36.5	0.100	3.650	2.778
069	Beef, roast w/ m gravy	1.0	20.0	36.5	0.050	1.825	1.389
071	Breakfast bake	2.0	20.0	36.5	0.100	3.650	2.778
072	Chicken, roast w gravy	1.0	15.0	36.5	0.067	2.433	1.852
073	Eggs,scrambled w/ ham	2.0	20.0	36.5	0.100	3.650	2.778
074	Egg loaf w/ cheddar	2.0	20.0	36.5	0.100	3.650	2.778

Simple analysis of this Table can lead to several interpretations of the data as follows (see Appendix A for full Table information):

a. Persons eating under the Ten-Day Basic Meal Plan Cycle consume by volume approximately--

(1) 3 1/2 times more meat and eggs (entrees) than vegetables.

(2) 2 1/2 times more meat and eggs than starches.

(3) 20% more meat and eggs than fruits and desserts.

(4) 3 times more fruits and desserts than vegetables.

(5) 2 times more fruits and desserts than starches.

(6) 1 1/2 times more starches than vegetables.

b. A person eating from the Tray Pack system consumes approximately 1/3 of a tray of food per day and 132 trays per year average.

c. Nearly 5.5% of all food consumed by volume is Blueberry Cake while only 1.37% is Roast Beef in Gravy. This suggests the obvious--that a person eats 4 times as much Blueberry Cake as Roast Beef. However, the not so obvious is that 1 in 19 food items consumed by a person is Blueberry Cake, a per item rate that soon enough anyone should grow tired of.

d. If each of the Alternate Tray Pack Items were substituted once a year this would account for about 1% of total yearly consumption.

Note:

This type of information may be beneficial to the nutritionists and procurement officers involved with the Tray Pack System.

Manipulation of this data (the input parameters) prior to running NATPRO would allow those involved with the Tray Pack System to configure a system comprised of several different Ten-Day Meal Plans that could be run independently or simultaneously. One could also set up an Alternate Item substitution configuration and run it with the desired Ten-Day Meal Plan. One could also design and run a 30- or 50-Day Meal Plan Cycle which might incorporate all 73 menu items. The parameter tables have been set up to allow for the above types of Tray Pack System manipulation. With this ability, the decision makers involved with the Tray Pack System can quickly test and see results concerning different meal plan scenarios and how these scenarios would affect production and inventory of the trays.

2. Table of Production Demands

The table of production demands is a structured display of the Production Rates required to meet the desired demand which is input interactively or via one of the demand parameters. This table is generated in its entirety for each demand level input. The table can be broken down into 5 sections as follows:

a. Tray Pack Production Requirements
b. The Ten-Day Basic Meal Plan Items
c. The Ten-Day Basic Meal Plan by Food Categories
d. The Alternate Tray Pack Items
e. The Alternate Tray Pack Items by Food Categories

Table 2 is a sample set of output from running NATPRO. Again, see Appendix A for a detailed description.

TABLE 2. Sample Data from the Table of Production Demands

Tray Pack Production Requirements, per Item
Based on Annual Demand to Feed 2568 Persons per Day

	Production per Year[a]	Production per Day[a]	Production per Hour[b]	Production per Minute
Ten-Day Basic Meal Plan Items				
Entrees	131258.92	525.04	70.00	1.167
Starches	55310.12	221.24	29.50	0.492
Vegetables	38435.84	153.74	20.50	0.342
Fruits and Desserts	112495.17	449.98	60.00	1.000
Basic Meal Plan Totals	337500.06	1350.00	180.00	3.000

[a]250 days per year

[b]8 hours per day

The main use of this Table is to suggest to its user the production rates required to meet a known feeding demand. Such data can also be used to address the Tray Pack Producibility issue.

If one can reliably estimate the production rates of several existing production lines, as well as some theoretical production lines, it seems logical that one can generate a configuration of these lines that will support any desired level of production. At this point, one can reasonably assess whether production under such a configuration is recommended. One can also work the problem in the other direction. Again by knowing the production rates of a number of different lines, one can propose several different production line configurations (systems) and determine the feasible or infeasible levels of production of these systems. If a desired system is found, one can enter, as demand input to NATPRO, that number of trays desired as output from the system. NATPRO will then give as output, in the Table of Production Demands, the numbers of trays of each menu item required.

The data generated in the Table of Production Demands can be interpreted in many ways. Assuming one needs to fill a distribution center with inventory, one could set the number of trays to be produced in a year as the maximum number of trays that can be stored in the distribution center. This allows one to interpret the production per year column as the number of trays of each item one has to order (or to be produced) to have a balanced level of inventory. If some inventory is presently on hand, one needs only to subtract the on-hand inventory from the value generated by NATPRO and produce or order this difference to rebalance and restock the inventory.

One may also use the production per year figures to determine the contract sizes of the individual menu items when a known Tray Pack demand must be produced in a balanced manner.

There is no need to manipulate the output in the Table of Production Demands since this is done by inputing different demand requirements. However, if one is interested in production rates or demands needed on a

per-month (30-day) or 90-day basis, these rates and tables can be generated by changing the production days per year from 250 to the desired level. This can be done by entering the NATPRO program and changing the value of the variable "NUMDAY", the number of days per year. If one wishes to see production demands based on two-shift production days, one can change the variable "NUMHRS" from 8 to 16 or any desired number of hours per production day. When doing this, the user in essence is defining his production year.

D. NATPRO and Tray Pack Producibility

NATPRO and its output have been shown to be powerful analytical tools. One need not look far to see how NATPRO can be used to address the Tray Pack Producibility issue.

Each facility within the present Tray Pack System has been studied by the UMASS PEP Group to determine present production line capability at each site. In Chapter IV, generic production lines are presented, all of which suggest a per-line production rate in trays produced per minute. These theoretical and existing line rates can be used to define the production capability of the existing Tray Pack System or any designed system based on any combination of these production lines.

NATPRO generates a "number" needed to address these levels of production. This number is the per-minute production rate required to fulfill the input demand (in trays or persons to be fed per year based on 250 production days, one 8-hour production shift per day).

NATPRO can also use its internal parameter tables and the above two production constants to build two linear functions. One function equates the Tray Pack demand to the per-minute production rate; the other, persons to be fed to the per-minute production rate. Since both functions equate zero demand to a zero production rate and are linear, we can graphically represent any demand to its associated production rate based on the existing NATPRO parameters. This is done by setting up a linear graph which compares

both types of demand to production rate, see Figure 2. By plotting any pair of points generated by NATPRO (one point representing trays produced at a defined production rate per minute), the other persons to be fed by a system producing at a defined production rate per minute. One can draw two lines from the origin, one through each of these two points and thus define any production line or production system based on the existing NATPRO parameters.

If one decided to change the NATPRO parameters, for example to a 300-production-day schedule with two production shifts a day, a new graph defined by this Tray Pack production system would need to be generated. If one changed the present Ten-Day Meal Plan to some other menu item configuration, one again would have to generate new graphs to represent the new values for the "persons to be fed" function.

What is important to note is that each graph can be generated by simply inputting the new parameters into NATPRO, running the program, reading the output tables for the desired values, plotting these points on a piece of graph paper, then drawing two lines. Immediately one can determine the output per line or per system based on the new parameters.

Generating graphs based on any desired production requirements makes one's job of addressing Tray Pack producibility at those levels a relatively simple one. Thus, given a specific Tray Pack requirement, can a reasonable number of production lines be assembled in a reasonable amount of time to fulfill such requirements? Using the data NATPRO and the graphs generated, along with our estimated line rates, one can determine just what it takes to meet these requirements and thus make appropriate recommendations.

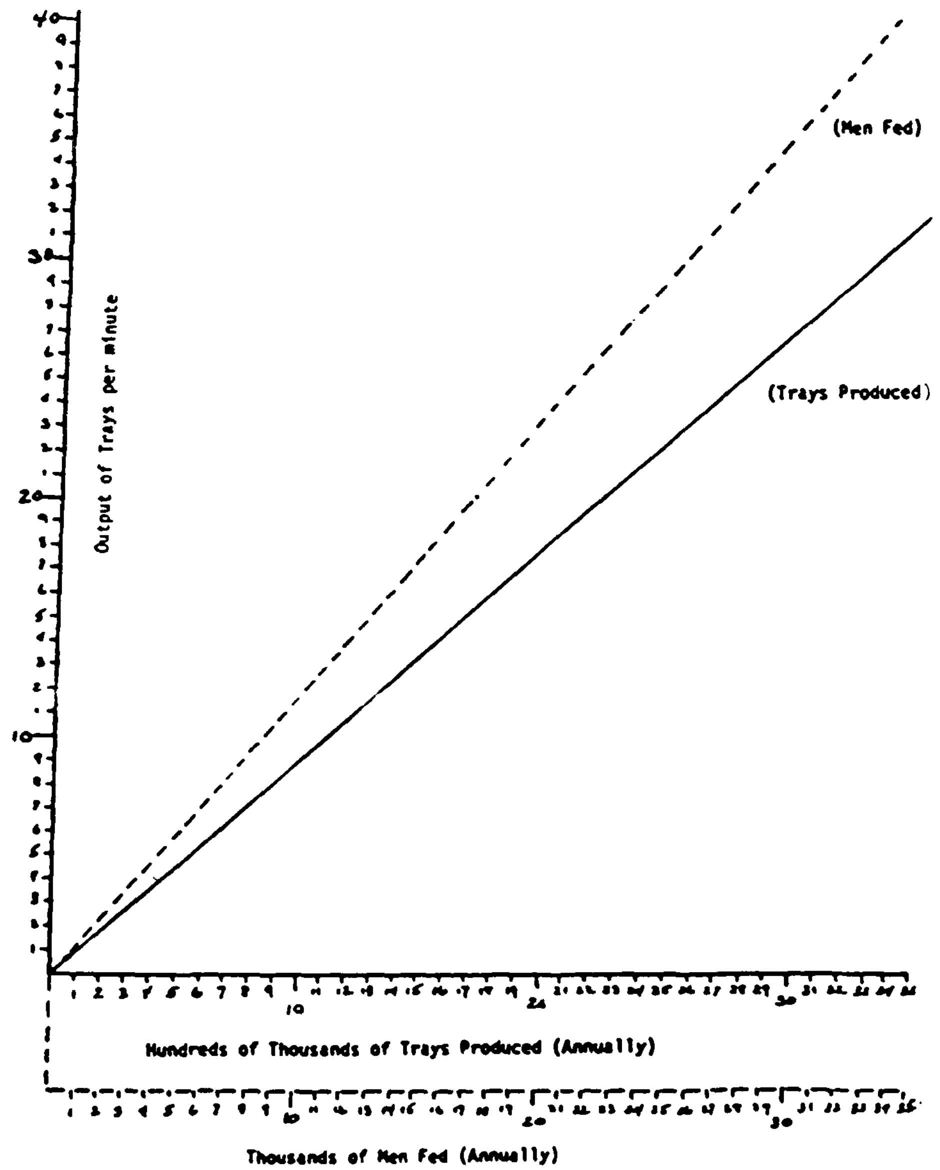

Figure 2. Tray Pack production rate vs. demand

E. NATPRO Extensions

NATPRO and the graphs it allows one to generate were developed to allow one to look into the Tray Pack System as a whole and how it interacts with itself. The actual power of NATPRO as an analysis tool was not understood until the NATPRO program had been run a few times and a few graphs had been drawn in an attempt to model the existing Tray Pack production lines and system.

One finds little difficulty in improving upon and extending the capabilities of NATPRO and these graphs as analysis tools and data generators for the Tray Pack System.

Recommended improvements to NATPRO as it presently exists would be as follows:

1. Reformat the NATPRO parameters, where necessary, so that they can handle several unique meal plans of varying durations.

2. Make appropriate programming changes to allow for combining the individual meal plans into any grouping desired. In this way, one could enter all the possible meal plans conceivable and then analyze different configurations by initializing the parameters in say, the fourth, fifth, and eighth columns. If there were only eight columns then the first, second, third, sixth, and seventh columns of data would be repressed and analysis would be performed on meal plans four, five, and eight as desired.

3. Develop multipliers that can be applied to the NATPRO output which will make this output more applicable to the problem being solved. These multipliers would include the following:

   - Waste
   - Damage
   - Inventory

   For each of these items, estimates should be generated and the functional equations written into NATPRO. The user should have the capability of setting and resetting the values of these parameters once these equations are set up. The user should be able to enter a value, say 10% waste, and have this figure applied to the output, or enter the demand and have a routine within NATPRO find the estimated waste, if one finds that waste varies over demand.

4. Enhance NATPRO so that it has the capability of accepting as input the Tray Pack System production rate, in trays per minute, and generate all its present output.

C H A P T E R   I V

Line Design and Analysis

A. Introduction

This section summarizes equipment and personnel requirements for filling and processing of Tray Packs at line speeds ranging from 4 to 40 cans per minute.

B. Equipment Specifications

The 44 main menu items and the 29 alternate items can be divided into four groups according to their filling and processing requirements as shown in Table 3. Group I includes retorted menu items that can be filled in a single step using a piston or rotary pump type filler. Group II includes retorted items filled in two separate steps. Group III includes retorted items that require labor intensive, multistep hand filling. Group IV includes the baked items--all of which are filled by single step pumping.

Most companies would key their line speeds and personnel to the speed of their available seaming equipment as this equipment is quite expensive and relatively slow. The manufacturer of the fastest seamer available ("Yaguchi," Industrial Marketing International, Kinderhook, NY) claims their machine can close 30 cans per minute if the cans are empty and up to 25 filled cans per minute on some items. Producers with experience with the machine suggest that such figures are too high for sustained, problem free production. In this work, we assume a rate of 20 cans per minute for the Yaguchi under the assumption that spillage problems inherent to this speed can be overcome by some method, such as by development and use of a clip system to hold the lids onto the cans until the start of the seaming operation proper. Without such a system, attainable speeds for products containing low viscosity liquids are limited to about 8 cans per minute. The Callahan 527 seamer (Rollasen Engineering Co., Fern Park, FL)

TABLE 3. Grouping of menu items

Group	Process Method	Filling	Menu Items
I	Retort	One Step	Beef Stew, BBQ Beef, Creamed Ground Beef, Chicken a la King, Eggs/Ham, Eggs/Mushrooms, Breakfast Bake, Apple Sauce, Apple Dessert,Blueberry Dessert, Cherry Dessert,Potato Salad, Orange Nut Cake, Chocolate Pudding, Cherry Nut Cake, Chili Con Carne, Chicken Noodles, Chicken Stew, Creamed Corn
II	Retort	Two Step	Pork Slices/Gravy, Slices of Roast Beef, Meat Loaf, Golden Roast Chicken, Ham Slices/Brine, Canadian Bacon, Slices of Turkey/Gravy, Franks/Brine, Pork Sausage, Pepper Steak, Rice, Potatoes/Butter Sauce, Buttered Noodles, Glazed Sweet Potatoes, Macaroni/Cheese, Mixed Vegetables, Three Bean Salad, Whole Kernel Corn, Carrots/Brine, Peas/Mushrooms, Green Beans, Peaches/Syrup, Pears/Syrup, Fruit Cocktail, Pineapple/Syrup, BBQ Pork, Beef Pot Roast, Pork Slices/Gravy, Swiss Steak, Spaghetti/Meatballs, Swedish Meatballs, Chicken Cacciatore, Chicken Breasts/Gravy, Beef Tips/Gravy, Macaroni/Beef, Macaroni Salad, Potatoes/Chicken Sauce, Spanish Rice, Glazed Carrots, Lima Beans, Peas/Carrots, Stewed Tomatoes
III	Retort	Special	Lasagna, Stuffed Peppers, Stuffed Cabbage
IV	Oven	One Step	*Blueberry Cake, Coffee Cake, Chocolate Cake, Spice Cake, Fruit Cake, Marble Cake, Pound Cake

* These items are not retorted.

has been used by one processor at speeds of 15 cans per minute; their 227 model, however, is limited to about 4 cans per minute.

Turning to the Group I foods, Figure 3 shows a schematic diagram for filling and closing at a rate of 20 cans per minute. As shown, trays are manually unstacked, inspected, and placed into a spray type washer. They are then automatically turned right side up and placed onto a belt conveyor. A piston or rotary gear type filler, activated by a light beam, is used with a ribbon type nozzle to fill the trays. Lids, following inspection and washing, are manually placed and clipped onto the trays. A check weigher/channelizer (e.g., "Mark II" by Icore Corp., Mountain View, CA) is used to separate under- or overfilled trays which are adjusted manually and placed into the buffer area before the seamer. After seaming, the trays are inspected and placed into retort baskets for processing with either agitated (e.g., "Rotomat" by Hermann Stock, Neumunster, Germany) or still (e.g., FMC Corp., San Jose, CA) retorts.

As the check weigher/channelizer is much faster than the seamer, it might be logical for producers interested in increasing production to use two seamers on a single line as shown in Figure 4. The channelizer would be programmed to alternate output of correct weight trays between the two seamers.

Turning to the Group II foods, Figure 5 shows a schematic diagram for filling sliced meat items at 20 cans per minute as an example of a two-step filling operation. As can be seen, most of the diagram is the same as before except that an additional check weigher/channelizer must be used as well as an arrangement for slicing and placement of the slices into the trays. Slicing could be facilitated by forming tempered meats into well defined shapes using a press (e.g., "Dyna-form" model by Bettcher Industries, Inc., Vermilion, OH) as part of the preparation processes. Slicing follows (using, e.g., three Bettcher Model 20 slicers in parallel) with the slices deposited in stacks of the correct number onto the conveyor belt for easier manual placement into the trays.

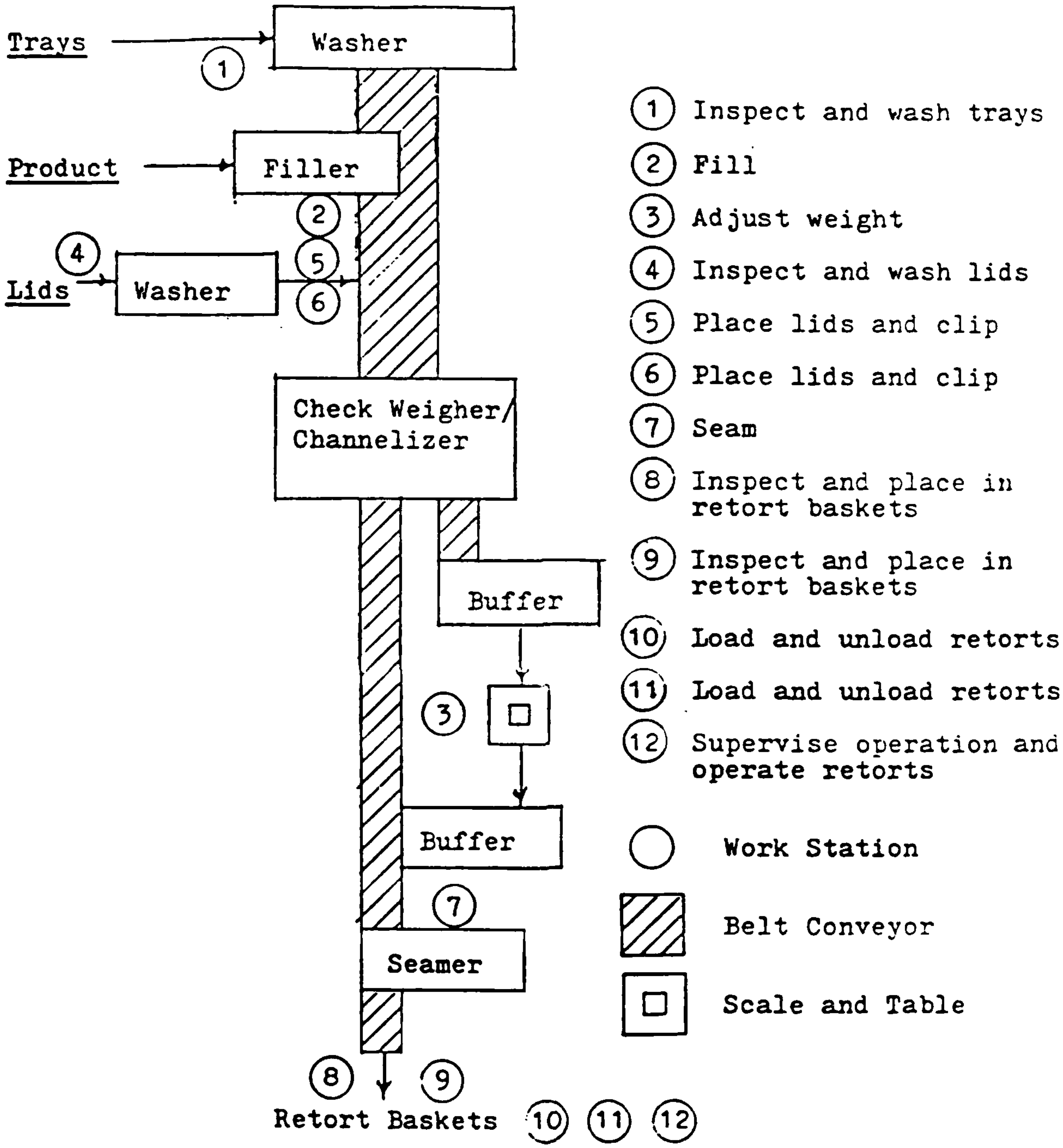

Figure 3. Group I Tray Pack line (20/min).

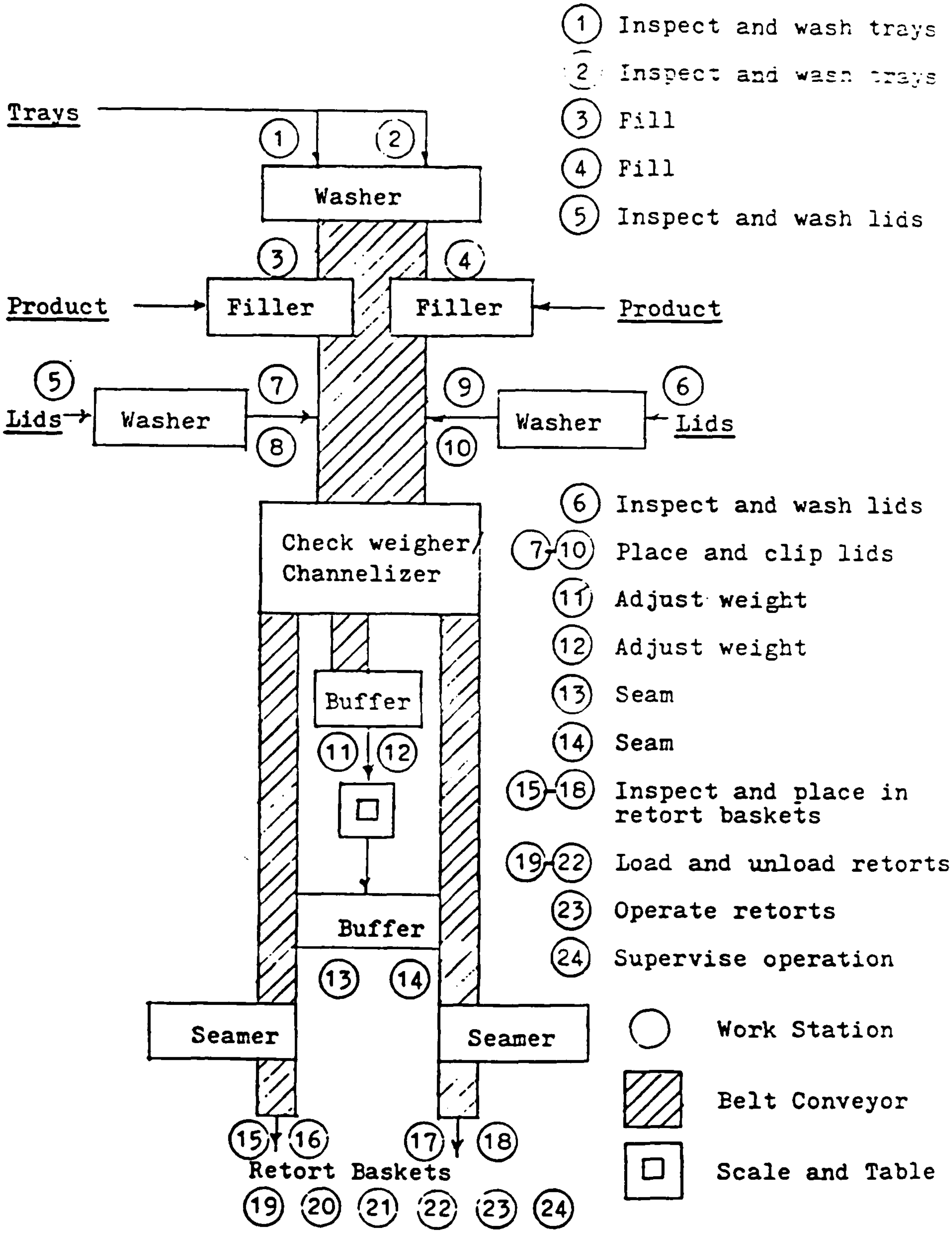

Figure 4. Group I Tray Pack line (40/min).

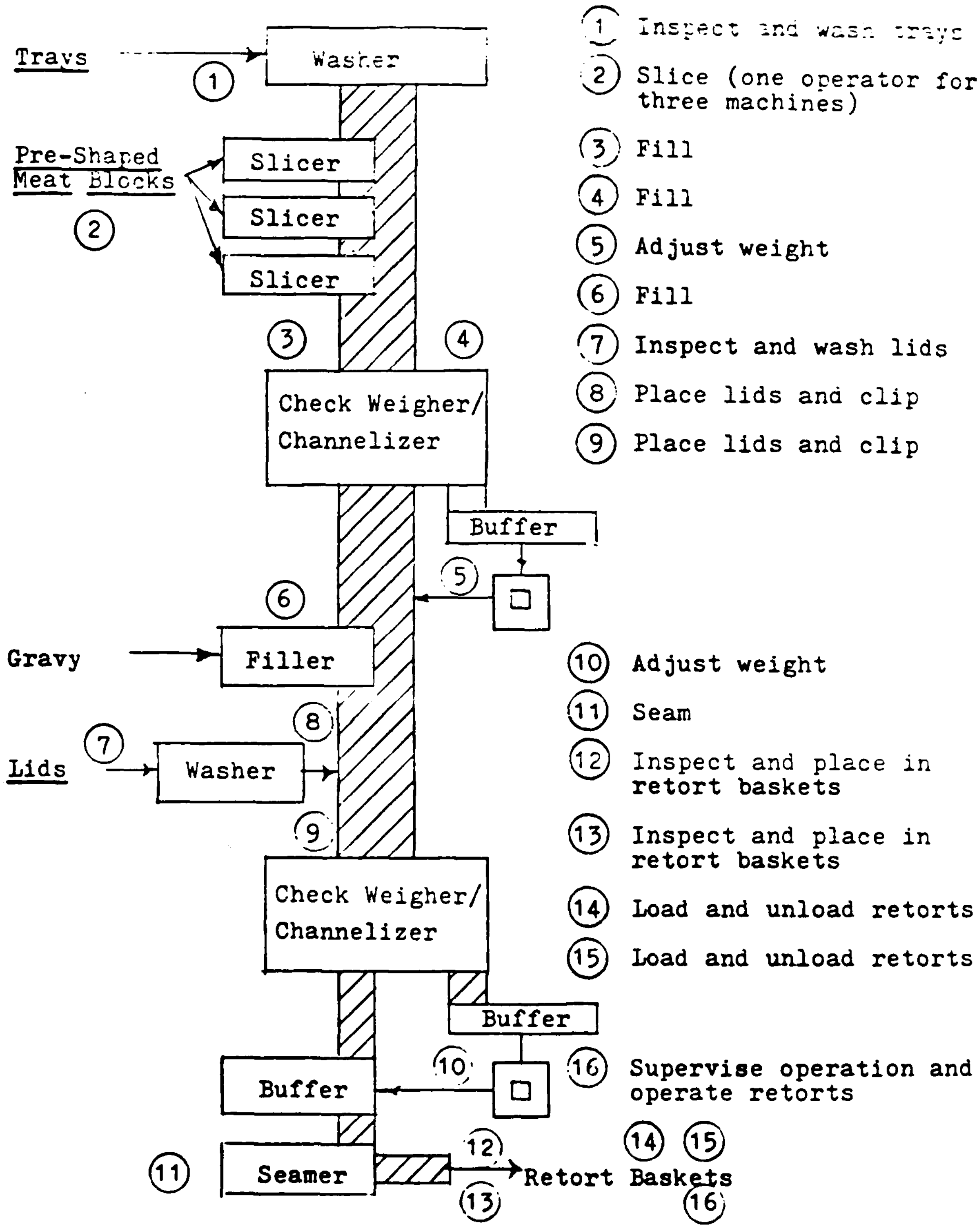

Figure 5. Group II Tray Pack line (20/min).

An additional Group II example is shown in Figure 6. This figure shows filling of a bulk fill item, (such as rice) at a rate of 10 cans per minute, currently sustainable without development of a spill prevention system. At this reduced production rate, electronic scales can be substituted for the more costly check weigher/channelizer systems.

A final Group II example is shown in Figure 7 which depicts a processing line geared to the 4 cans per minute rate of the Callahan 227 seamer.

Group III consists of those foods which involve multistep ingredient addition such as lasagna, or considerable hand work in forming and placing foods such as stuffed peppers and stuffed cabbage. Figure 6 is relevant to this group except that the belt conveyor would have to be extended to allow room for the workstations required. (For example, a lasagna test production run at 10 trays per minute used 12 such workstations). Each workstation requires an ingredient table; workers simply place ingredients into the trays using a volumetric scoop or by count. As before, net weight adjustment is achieved by addition of the final ingredient while the tray is on a scale.

Production of Group IV items is shown in Figure 8 wherein a number of changes from the other groups can be noted. First, the trays are not washed but parchment is used above the product. Second, the trays must be crimped (first step in the normal seaming operation). Third, an oven is used rather than a retort. Fourth, the product must be sealed after processing and cooling.

C. SIMAN

SIMAN (SIMulation ANalysis) is a digital simulation language that allows one to model the production lines presented in the above section. With such a simulation package one can model the existing production lines as they presently exist and verify their known production capabilities. Once this has been done successfully and one can reproduce the existing

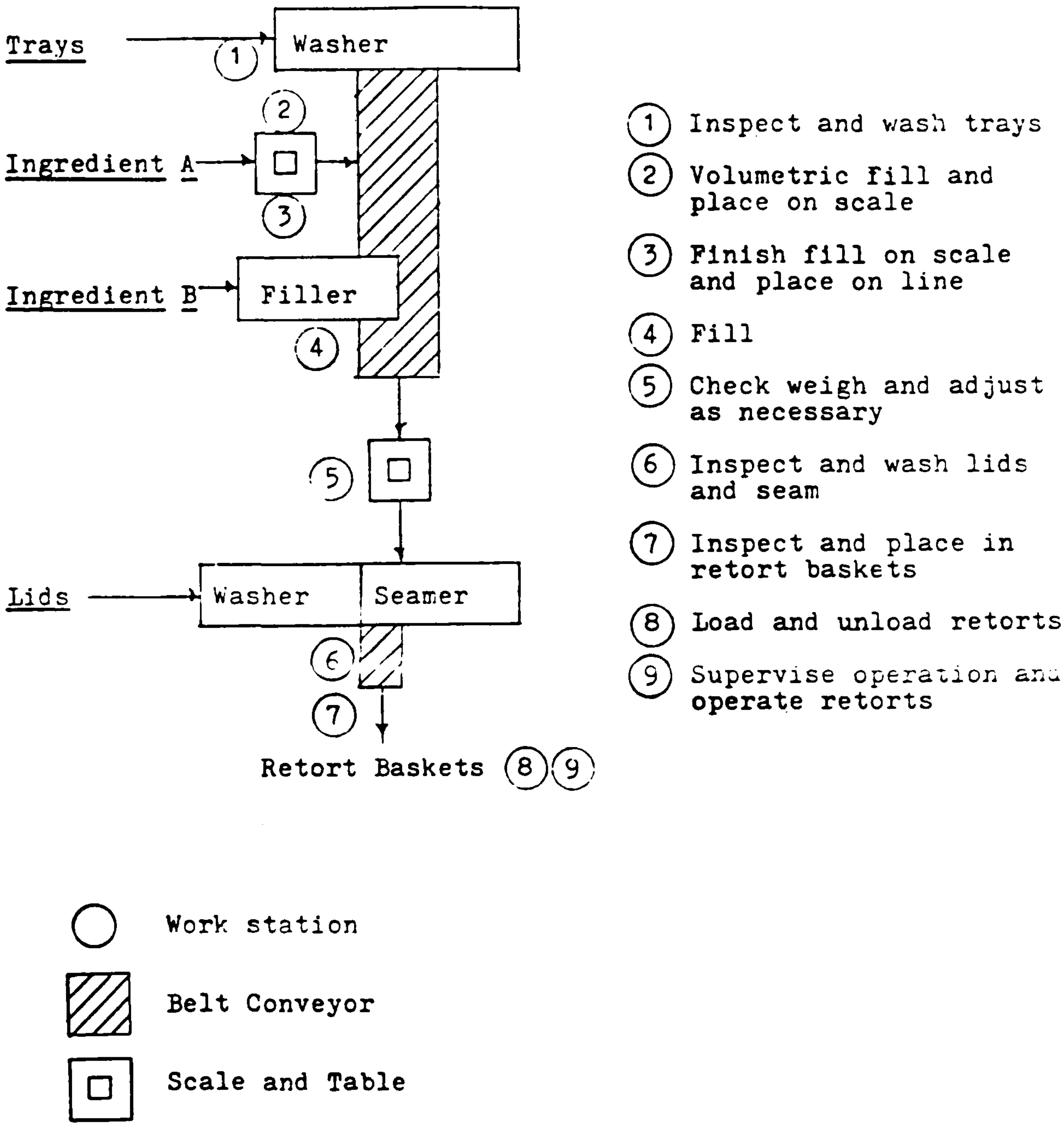

Figure 6. Group II Tray Pack line (10/min).

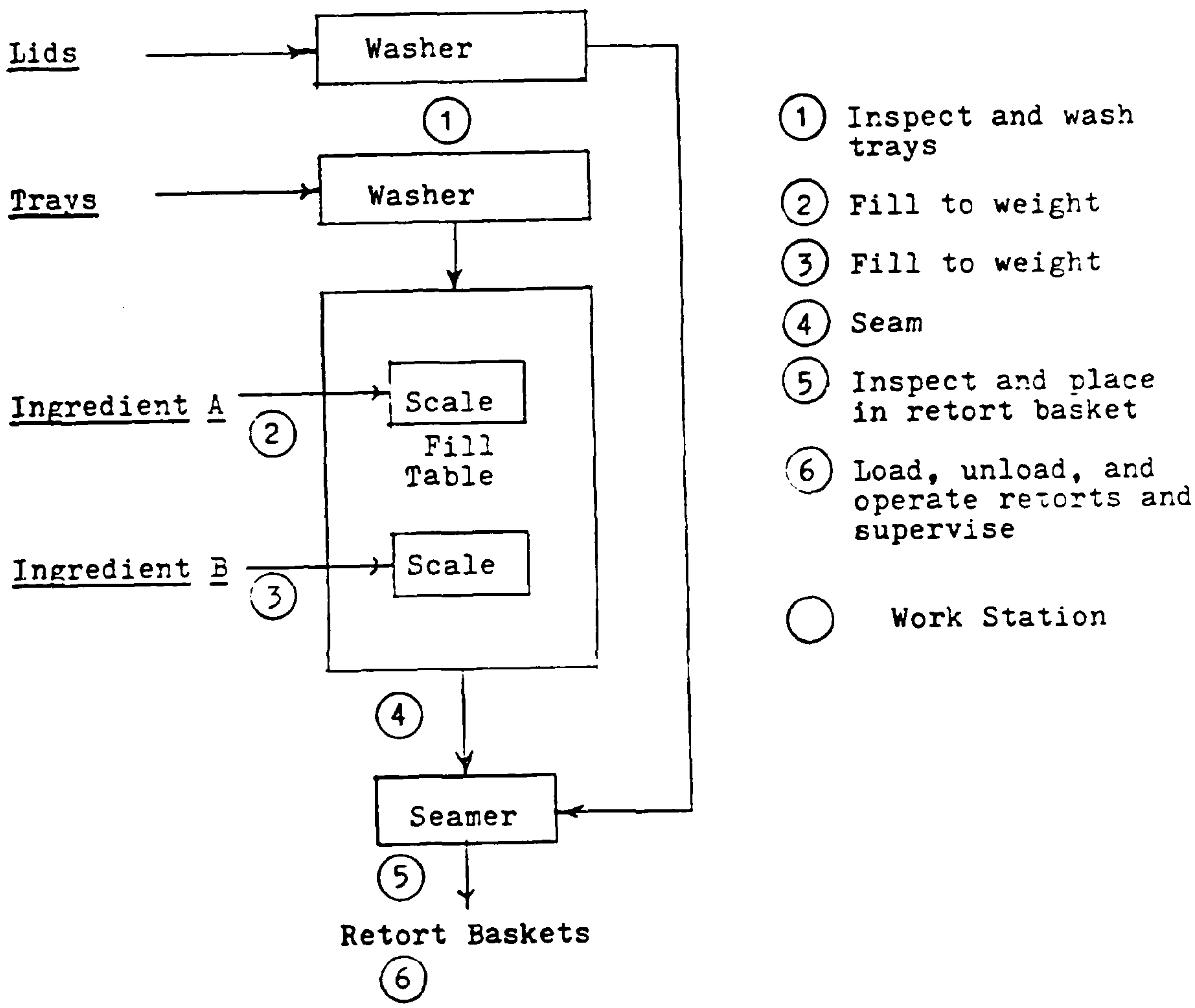

Figure 7. Group II Tray Pack line (4/min).

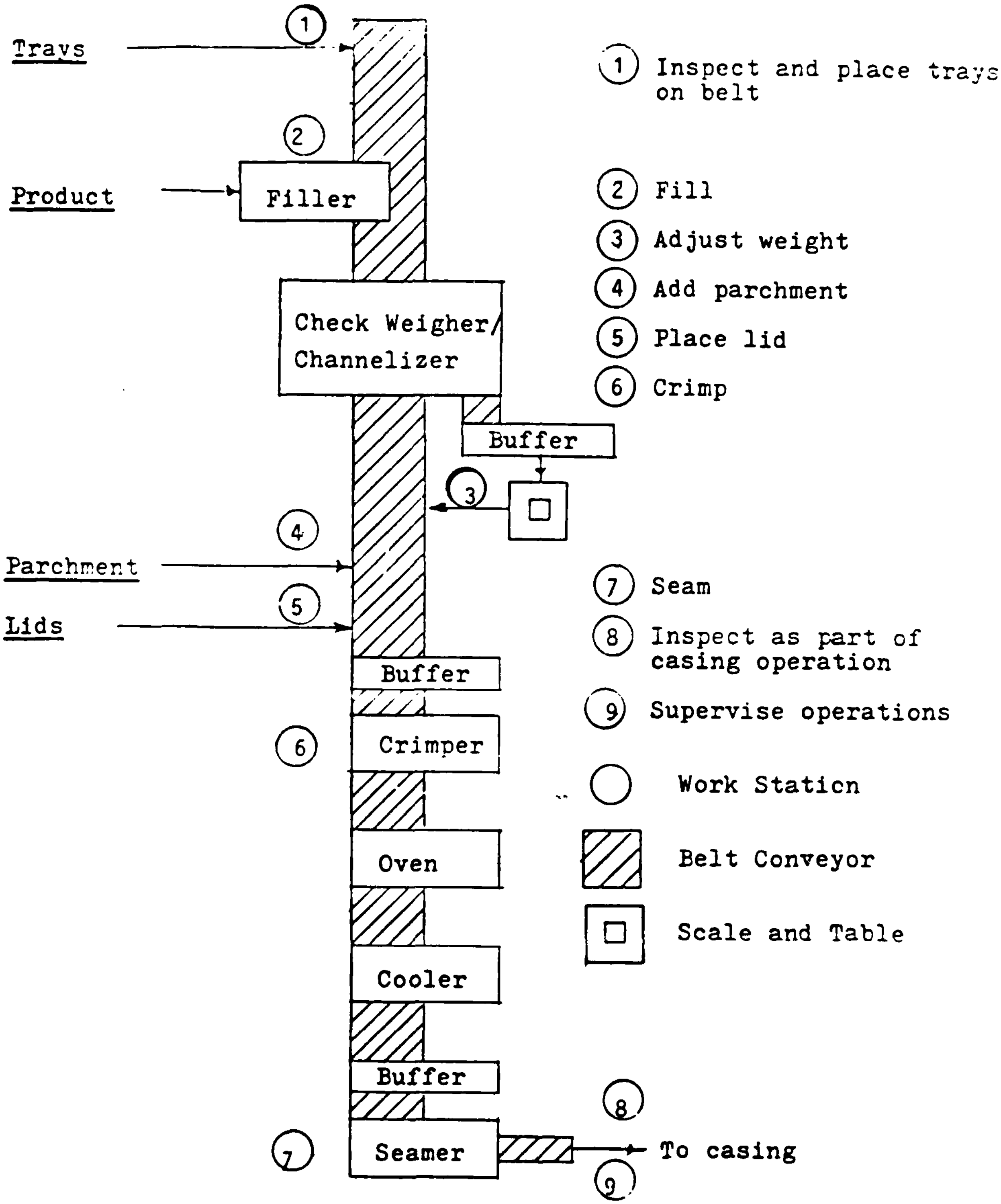

Figure 8. Baked Menu item Tray Pack line (20/min).

production rates by representing the existing lines, then one should be able to model the proposed lines and generate valuable data based on these lines.

This data should indicate how much automated equipment may be needed to support production at a rate of 20 trays per minute, 25 trays per minute and 50 trays per minute, since with SIMAN, one can continually model and add pieces of equipment until the required output in trays per minute is attained. With SIMAN one can model complementary equipment and use SIMAN to determine the best configuration of the lines based on these alternatives. Once an optimal line configuration has been determined, one can perform sensitivity analysis on each optimal line and determine just what output rates each piece of equipment should be set at to allow for a steady state line output at the desired level of production.

With SIMAN, one can model equipment breakdowns. By simulating such occurrences, one can determine potential bottlenecks prior to setting up a production line. One may find in doing so that a relatively inexpensive piece of equipment sitting idle or in a warehouse may be extremely valuable at times of breakdown. In essence, SIMAN allows one to model line problems and determine what corrective measures, if any, are necessary to allow the line to continue to operate at optimal output.

An example of a SIMAN Program and SIMAN Output appear in Appendix B.

D. Production Line Capacities

While the capabilities of the existing production lines, the existing production system, the proposed production lines or the proposed production system have not been addressed yet, this will follow after mention of a few observations encountered at the sites.

At each site, prior to visiting the production lines, the team asked what were the line rates on the product being run. In general all lines operated below the rates suggested to us. The team understands that it was

receiving the optimistic (or optimal) rates; however, on several occasions no single tray came off the line at these suggested rates. This suggested that such line rates may not be attainable, and therefore a range of line and system rates based on the existing lines will be presented. This range will be based on a pessimistic estimate, expected estimate (generated by the observations), and an optimistic estimate (given by the producers). The following Table of Estimates is the number of trays per minute each producer is estimated to be able to produce with the seamers they presently have on site; n.b. Bryan and Shelf Stable have two seamers.

TABLE 4. Table Of Estimates
(trays seamed per minute)

PRODUCER	OPTIMISTIC	EXPECTED	PESSIMISTIC
Vantage	4.0	3.0	2.0
Bryan	6.0	4.0	3.0
	15.0	12.0	10.0
	21.0	16.0	13.0
Vanee	22.0	12.0	8.0
Shelf Stable	3.0	2.0	2.0
	12.0	10.0	8.0
	15.0	12.0	10.0
SoPaCo	12.0	10.0	8.0
Sterling	15.0	12.0	10.0
Totals	89.0	65.0	51.0

Based on the above table, three projections can be generated reflective of yearly production of trays based on the present Tray Pack System. These are the optimistic, most-likely, and pessimistic system production rates.

Optimistic Rate	10,012,500	Trays Per Year, Per Production Shift
Most-Likely Rate	7,312,500	" " " " " "
Pessimistic Rate	5,737,500	" " " " " "

The above numbers translate into the following persons being fed by such systems.

Optimistic	76,184	Persons Fed on a Daily Basis for One Year
Most-Likely	55,640	" " " " " " " " "
Pessimistic	43,656	" " " " " " " " "

The above numbers suggest that the present Tray Pack System at best can produce about 10 million trays per year running one production shift, if everything goes as the producers expect. At worst, about 6 million trays can be produced, and the group expects about 8 million trays can be produced by the present system, if no enhancements to the present lines are implemented. Note that the present estimated output of Freedom Foods would be about 0.3 million trays per year.

If enhancements are made to existing equipment and the proper automated equipment is purchased by each of the producers, each production line in the system having a Yaguchi Seamer should be able to produce at 20 trays per minute. This equates to 140 trays per minute for the existing 7-site system. If 20 trays per minute can be attained, then the approximate yearly output rate increases to 15,750,000 trays. This is 2,250,000 trays per line. The number of persons fed on a daily basis climbs to 119,840 persons for the system.

If one assumes a seamer capable of closing 25 trays per minute or 50 trays per minute can be designed and implemented, then a 7-site system should be able to produce 19,687,500 trays per year for the 25-per-minute seamer. For the 50-per-minute seamer 39,375,000 trays can be produced per year per production shift system-wide. Per line rates equate to 2,812,500 trays per line for the 25-tray-per-minute seamer and 5,625,000 trays per line for the 50-tray-per-minute seamer.

CHAPTER V

Conclusions

The UMass PEP team observed, reviewed on-site, discussed and evaluated all but one of the seven current producers of Tray Packs for the military. A wide range of equipment and methods in use was found, but also many common problem characteristics among the various production lines.

All producers used manual methods to handle Tray Packs (empty and filled) - used automatic or machine-assisted fillers for transferring food materials to Tray Packs, and powered conveyors saw limited use, if ever. Almost all producers had definite feelings about production rates they could achieve. The limited opportunities to test their figures demonstrated that they were usually optimistic; sometimes they were off the mark.

There was no evidence that any production line observed had been designed in an engineering sense. The manufacturing expertise that existed at each location was used to set up production lines, but no engineered lines existed, such as would occur with sophisticated fillers, conveyors, weighing apparatus, etc. normally found in high-speed lines.

CHAPTER VI

Recommendations

A partial list of recommendations appropriate for continued examination beyond the initial PEP project report is presented below. These recommendations are designed to address the key issues of producibility in order to increase the production line rates above and beyond the 25 to 50 cans per minute and at the same time do so in a cost-effective manner. The order of the recommendations does not necessarily reflect their order of importance. The recommendations are broken down into the three major categories defined earlier, namely: PEP Engineering & Planning, PEP Engineering Design, and PEP Engineering Control.

A. PEP Engineering & Planning

These recommendations affect the overall planning of producibility at the Tray Pack system level.

1. Specifications:

Review menu item specifications to:

- Examine the need for items that require individual piece placement into trays
- Examine the need for various specifications and quality grades
- Examine detail equipment suggested for production.

Supporting Information:

Production of menu items that require hand placement of individual pieces into trays is more costly than when bulk filling can be used. For

example, there appears to be no reason to specify peach or pear halves rather than slices.

Initial production runs for nearly all of the menu items have been completed. In our discussions with producers, however, a wide variety of producibility issues were raised. For example, it is not necessary to pre-cook pasta items before placement in the tray. Also, certain USDA grade specifications seem overly restrictive. Finally, some products could be retorted at temperatures higher than 240°F.

If lists of suggested production equipment were available, it might facilitate quotations by new producers, thus providing a further guarantee of competitive bidding.

2. NATPRO Development:

Further the development of NATPRO so that costs and additional menu planning analysis can be carried out with Natick's computational capabilities.

Supporting Information:

NATPRO could be a valuable planning tool at the system level for examining different production and demand scenarios, especially with the incorporation of production costs. Additionally, graphics could be added to the program so that more easily interpretable results would flow from the program.

Other enhancements to NATPRO could include:

a. Routines which would estimate waste, damage, and inventory levels associated with the Tray Pack System. These estimates would have to be developed and would have the ability to change with demand as well as time. The need

for these parameters is obvious--to more accurately generate production and cost data associated with the Tray Pack System.

b. Routines which would allow the user to play "WHAT IF" with the Tray Pack System.

<u>**Example**</u>: Suppose there is a need to know if the Tray Pack System could produce enough trays to support the feeding of 500,000 persons for 30 days with a 30-day lead time with a present inventory capable of feeding 500,000 persons for 40 days.

Such a routine could tell you if the system could produce to the required level and, if not, it would tell you--

- by how much the system failed
- what level of added production would be required to attain the needed level
- and any other information that Natick might require of such a system.

3. <u>Optimization Software</u>

Problems with Tray Pack producibility lend themselves to software optimization development at the system planning level, among which the following problem area appears most relevant: Tray Pack Facility Optimization.

Supporting Information:

As a followup analysis, building upon the results of the demand analysis program NATPRO, an optimization analysis could be performed to examine the number of facilities and production lines necessary to meet Tray

Pack demand with minimum cost. The optimization program would have to consider the producer's production rates for the individual items and any facility capacity constraints impinging on the required demand for the product. Linear and Integer Programming models could be constructed to carry out this optimization analysis.

B. PEP Engineering Design

The set of recommendations contained in this section concerns the production line designs themselves for the Tray Pack items.

1. Spillage Problem:

Identify and develop methods and/or devices to control spillage problems met in transferring trays into the seamer thus enabling all products to be produced at a constant, maximum rate.

Supporting Information:

Current production rates are limited mainly by the speed of the seaming operation. There are two factors that influence seaming rates:

- The inherent maximum speed of the machine (which presently ranges from approximately four to thirty cans per minute)
- Spillage problems met in transferring cans with low viscosity products from the last filler into the seamer.

Producers are currently limited by spillage problems to under eight cans per minute on some items. If lids could be placed on the cans and held in place until the can is in the seamer, production speeds for all products should increase to at least twenty cans per minute. One possible method of holding the lids in place would be to develop and use a clip attachment and removal system (the removal system becoming part of the seamer itself).

2. Filling Problem:

Adopt or develop mechanical aids to speed tray filling operation.

Supporting Information:

At the present time, placement of specific count items into the trays is done by hand. The large number of menu items precludes development of devices to totally replace hand placement. Moreover, an important inspection operation is eliminated if such totally mechanical placement is achieved. Nevertheless, collection and arrangement of pieces into a tray loading pattern is practiced in a variety of food processing lines. Selection and implementation of equipment to facilitate such preassembling should allow labor and physical space requirements for tray filling to be reduced.

Problems involved in placement of small particulates and pumpable liquid and semi-liquid foods are not as difficult to overcome as those with specific count items. Nevertheless, problems with uniformity, head space control, and cleanliness of the can seal area that were raised by various producers point to the need for further development work in this area as well.

3. Experimental Line Development:

Develop and assemble a full-speed developmental and demonstration production line.

Supporting Information:

Currently, there is little sharing of information between competitive producers of Tray Pack foods. Moreover, as contracts to date have been for small quantities, there has been little incentive to investigate semi-mechanized filling devices, lid clip arrangements, and work station improvements. Proper investigation of these topics would benefit all

producers and would prevent duplication of research efforts if performed in a neutral environment.

4. Assembly Line Balancing:

As part of the production line design, assembly line balancing could be carried out to define the tasks assigned to workstations on the line. Since the production lines are crudely developed at best in the plants right now, assembly line balancing techniques would be useful to the producers to define the optimal number of workstations, cycle time, and line configurations. Software again could be transferred onto Personal Computers so that producers could balance their own production lines.

C. PEP Engineering Control

The recommendations in this section concern control of producibility, namely the inventory, scheduling, line reliability, congestion and maintainability of the production lines related to producibility. Since most producers did not have well-engineered production lines, control problems of Tray Packs have not really emerged as key issues at the current time. Given our understanding of the type of control problems normally associated with production lines, these problems will eventually surface, so preliminary planning and software development in this area will eventually have some long-range impacts. There are two sets of recommendations in this area: Multi-Product Batch Scheduling, and Digital Simulation of the Product Lines.

1. Multi Product Batch Scheduling

As Tray Pack volume increases, utilization of resources (e.g., retorts, labor, space) will intensify between Tray Pack items and commercial items produced at a site. Multiproduct resource scheduling would be concerned with developing and utilizing software tools so that Tray Pack items and commercial items could be scheduled simultaneously so that due dates and resource utilization could be optimized. Also, these software

tools would be developed for personal computers so that producers would have ready, easy access to them.

2. Digital Simulation of Product Lines

Develop simulation and analytical models for the production lines via SIMAN, a digital simulation language, and other network flow models, so that changes in technology, line configuration, workstation changes can be examined as to their impact on production rates. This type of simulation analysis is not only useful for checking actual production rates before the lines are built, but for controlling problems associated with machine breakdowns, congestion, and overall line reliability.

Supporting Information:

Flow analyses could be developed for classes of tray items, and ultimately, each tray item if necessary. If a simulation of each item were developed, this information could be shared among producers as they are developing similar product lines so that producers do not make the same mistakes previously made with other producers, especially as new equipment items, labor changes are made, etc. The programs could be part of a technology transfer so that individual producers could have the software available on Personal Computer (PC) micros to set up and test the line configurations before actually constructing them.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-88/007 in the series of reports approved for publication.

LIST OF REFERENCES

1. R. Byrne, S. Baritz, R. Decareau, G. Hertweck, H. Kirejczyk and I. Nii. A Proposed Combat Food Service System for the Army in 1990. US Army Natick R,D & E Center, NATICK/TR-80/027. January 1980 (AD A113 311)

2. Letter of Agreement (LOA) For A Combat Field Feeding System. US Army Training and Doctrine Command, USATRADOC ACN44499. March 1981.

3. Combat Field Feeding System (CFFS). TRADOC Combined Arms Test Activity, TCATA Test Report FT 458. March 1983.

4. Barbara Edelman. Acceptance Ratings of Tray Pack Items: A Preliminary Report. US Army Natick R,D & E Center, NATICK/TN-84/007. June 1984.

5. Barbara Edelman, Robert Kluter and Deborah Yates. Acceptance Ratings of Tray Pack Items: Phase II. US Army Natick R,D & E Center, NATICK/TN-85/001. July 1985.

A P P E N D I X E S

APPENDIX A

NATPRO Output

Below is a sample listing of NATPRO output. A description of each block of output will be given following this listing. There are two demand parameters which have been set in this run. The first demand parameter generates the distribution of Tray Packs simulated with a production line able to produce three trays per minute. The second demand parameter generates a simulation depicting a line able to produce 20 trays per minute.

NATPRO is driven by a table of 114 constants. These constants are the number of trays per person, per ten-day cycle consumed for each of the 44 basic meal plan menu items, the 29 alternate menu items and 41 item numbers not in use, grouped by food category. Seven parameters make up the identity as well as the mathematical value of each of the 114 constants and are listed below.

- cpy(I)	cycles per year
- id(I)	menu item identification
- xitem(I)	menu item number
- f(I)	menu item description
- ppc(I)	portions per cycle
- ppt(I)	portions per tray
- ifc(I)	menu item food category

Cycles Per Year

This parameter represents the number of cycles per year each of the 73 active menu items will be used in throughout a year. This parameter is set from a value of 0.0 to 36.5.

Menu Item Identification

This parameter identifies each of the 114 menu item constants as either a "ten-day basic meal plan menu item", an "alternate meal plan menu item", or a "menu item not in use".

Menu Item Number

This parameter identifies each of the 114 menu item constants by the menu item number assigned by Natick.

Menu Item Description

This parameter uses the Natick description of the 73 menu items presently being produced.

Portions Per Cycle

This parameter represents the number of portions each menu item is served during each ten-day meal plan cycle.

Portions Per Tray

This parameter represents the number of portions in each of the 73 tray items.

Menu Item Food Category

This parameter identifies each of the 73 menu items as either an entree, starch, vegetable or fruit/dessert.

Once the 114 constants are generated by the above parameters and stored internally in the program, output can be generated. It should be noted that these parameter tables can be changed, added to, or subtracted from, and

this will not affect the NATPRO program as long as one follows the formatting criteria set up for each parameter. Such a change would be necessary if new menu items are to be added to the system, a second ten-day meal plan is initiated or any other occurrence necessitating a parameter change.

As previously mentioned, NATPRO can be run interactively or by having the user hard code a list of demand constants into the program. Output from NATPRO is the same regardless of the mode the program is run in. In fact, output is the same whether the input variable is trays to be produced or men to be fed per time interval.

A. The Table of Constants

This table is a structured display of the seven parameters used to represent the identity and mathematical values of the 73 active menu item constants and 41 item numbers not in use. The table is broken down into 5 sections as follows:

1. The Ten-Day Basic Meal Plan Items
2. The Alternate Tray Pack Items
3. Item Numbers Presently Not in Use
4. The Ten-Day Basic Meal Plan by Food Categories
5. The Alternate Tray Pack Items by Food Categories

1. **Main Menu Items**

TABLE A-1. Ten-Day Basic Meal Plan Items

Item No.	Item Name	Portions per Cycle	Portions per Tray	Cycles per Year	Trays per Person per Cycle	Trays per Person per Year	Overall Item Percentage
	Entrees						
002	Beef stew	1.0	13.0	36.5	0.077	2.808	2.137
003	Beef in barbecue sauce	1.0	15.0	36.5	0.067	2.433	1.852
004	Beef pepper steaks	1.0	15.0	36.5	0.067	2.433	1.852
017	Turkey slices w/ gravy	1.0	18.0	36.5	0.056	2.028	1.543
021	Ham slices	1.0	18.0	36.5	0.056	2.028	1.543
028	Frankfurters in brine	1.0	22.0	36.5	0.045	1.659	1.263
035	Meatloaf, mshrm gravy	1.0	20.0	36.5	0.050	1.825	1.389
042	Canadian bacon	3.0	18.0	36.5	0.167	6.083	4.629
058	Beef, ground, creamed	2.0	15.0	36.5	0.133	4.867	3.704
062	Pork sausage links	3.0	30.0	36.5	0.100	3.650	2.778
069	Beef, roast w/ m gravy	1.0	20.0	36.5	0.050	1.825	1.389
071	Breakfast bake	2.0	20.0	36.5	0.100	3.650	2.778
072	Chicken, roast w gravy	1.0	15.0	36.5	0.067	2.433	1.852
073	Eggs,scrambled w/ ham	2.0	20.0	36.5	0.100	3.650	2.778
074	Egg loaf w/ cheddar	2.0	20.0	36.5	0.100	3.650	2.778
105	Chicken ala king	1.0	15.0	36.5	0.067	2.433	1.852
114	Egg loaf w/ mushrooms	2.0	20.0	36.5	0.100	3.650	2.778
	Starches						
023	Scalloped potatoes	1.0	25.0	36.5	0.040	1.460	1.111
026	Beans with pork	1.0	25.0	36.5	0.040	1.460	1.111
044	Macaroni and cheese	1.0	12.0	36.5	0.083	3.042	2.315
064	Potatoes, buttered	2.0	25.0	36.5	0.080	2.920	2.222
067	Noodles, buttered	1.0	15.0	36.5	0.067	2.433	1.852
068	Rice, white	4.0	25.0	36.5	0.160	5.840	4.444
070	Potatoes, sweet, glaze	2.0	25.0	36.5	0.080	2.920	2.222
078	Potato salad	1.0	25.0	36.5	0.040	1.460	1.111
	Vegetables						
022	Three-bean salad	1.0	20.0	36.5	0.050	1.825	1.389
048	Beans, green	2.0	25.0	36.5	0.080	2.920	2.222

049	Peas and mushrooms	2.0	25.0	36.5	0.080	2.920	2.222
059	Corn, whole kernel	2.0	25.0	36.5	0.080	2.920	2.222
060	Carrots sliced	1.0	25.0	36.5	0.040	1.460	1.111
063	Vegetables, mixed	2.0	25.0	36.5	0.080	2.920	2.222
	Fruits and Desserts						
010	Cake, orange nut	1.0	20.0	36.5	0.050	1.825	1.389
011	Cake, cherry nut	1.0	20.0	36.5	0.050	1.825	1.389
013	Cake, spice	1.0	20.0	36.5	0.050	1.825	1.389
014	Cake, chocolate	2.0	20.0	36.5	0.100	3.650	2.778
018	Apple sauce	2.0	25.0	36.5	0.080	2.920	2.222
024	Apple dessert	1.0	25.0	36.5	0.040	1.460	1.111
031	Peaches, sliced	3.0	25.0	36.5	0.120	4.380	3.333
039	Pears, sliced	1.0	25.0	36.5	0.040	1.460	1.111
043	Cake, coffee, apple	3.0	20.0	36.5	0.150	5.475	4.166
050	Fruit cocktail	4.0	25.0	36.5	0.160	5.840	4.444
076	Pineapple, diced	2.0	25.0	36.5	0.080	2.920	2.222
081	Pudding, chocolate	2.0	25.0	36.5	0.080	2.920	2.222
113	Cake, blueberry	4.0	20.0	36.5	0.200	7.300	5.555

This section lists the 44 menu items in the Ten-Day Basic Meal Plan. Each item is grouped in one of the four food categories: entree, starch, vegetable or fruit/dessert. For each menu item the following information in displayed.

- Item Number
- Item Name (Description)
- Portions Per Cycle
- Portions Per Tray
- Cycles Per Year
- Trays Per Man Per Cycle
- Trays Per Man Per Year
- Overall Item Percentage

Item Number, Item Name (Description), Portions Per Cycle, Portions Per Tray and Cycles Per Year are the values stored in the NATPRO parameters with the same names.

Trays Per Person Per Cycle

This constant is generated by dividing each item's Portions Per Cycle by the Portions Per Tray.

Trays Per Person Per Year

This constant is generated by multiplying each item's Trays Per Person Per Year by the number of Cycles Per Year that item will be used (generally 36.5).

Overall Item Percentage

This constant is generated by summing the constants, Trays Per Person Per Year, getting a Total Tray Consumption Per Year constant. Then, dividing each Tray Per Man Per Year constant by the Total Tray Consumption Per Year constant gives the Overall Item Percentage versus the entire system for each item.

2. **The Alternate Tray Pack Items**

TABLE A-2. NATRPO Output

Item No.	Item Name	Portions per Cycle	Portions per Tray	Cycles per Year	Trays per Person per Cycle	Trays per Person per Year	Overall Item Percentage
	Entrees						
001	Pork slices w/ gravy	1.0	15.0	0.0	0.067	0.000	0.000
005	Lasagana	1.0	12.0	0.0	0.083	0.000	0.000
006	Swedish meatballs/gvy	1.0	20.0	0.0	0.050	0.000	0.000
007	Beef,pot roast w/gravy	1.0	15.0	0.0	0.067	0.000	0.000
015	Chili con carne	1.0	12.0	0.0	0.083	0.000	0.000
016	Spaghetti w/ meatballs	1.0	12.0	0.0	0.083	0.000	0.000
027	Peppers,stuffed w/beef	1.0	16.0	0.0	0.063	0.000	0.000
036	Beef swiss steak/gravy	1.0	14.0	0.0	0.071	0.000	0.000
037	Pork in barbecue sauce	1.0	18.0	0.0	0.056	0.000	0.000
106	Chicken with noodles	1.0	18.0	0.0	0.056	0.000	0.000
107	Chicken cacciatore	1.0	15.0	0.0	0.067	0.000	0.000
108	Chicken breast w/gravy	1.0	12.0	0.0	0.083	0.000	0.000
109	Chicken stew w/ gravy	1.0	12.0	0.0	0.083	0.000	0.000
110	Beef tips with gravy	1.0	18.0	0.0	0.056	0.000	0.000
111	Beef and macaroni	1.0	20.0	0.0	0.050	0.000	0.000
112	Stuffed cabbage	1.0	12.0	0.0	0.083	0.000	0.000
	Starches						
030	Rice, spanish	1.0	25.0	0.0	0.040	0.000	0.000
079	Macaroni salad	1.0	25.0	0.0	0.040	0.000	0.000
084	Potatoes/chicken sauce	1.0	20.0	0.0	0.050	0.000	0.000
	Vegetables						
041	Carrots, glazed	1.0	25.0	0.0	0.040	0.000	0.000
051	Corn, sweet, creamed	1.0	25.0	0.0	0.040	0.000	0.000
053	Peas and carrots	1.0	25.0	0.0	0.040	0.000	0.000
065	Beans, lima	1.0	25.0	0.0	0.040	0.000	0.000
085	Tomatoes, stewed	1.0	25.0	0.0	0.040	0.000	0.000

Fruits and Desserts

008	Cake, marble	1.0	20.0	0.0	0.050	0.000	0.000
009	Cake, pound	1.0	20.0	0.0	0.050	0.000	0.000
012	Cake, fruit	1.0	20.0	0.0	0.050	0.000	0.000
019	Blueberry dessert	1.0	25.0	0.0	0.040	0.000	0.000
020	Cherry dessert	1.0	25.0	0.0	0.040	0.000	0.000

This section lists the 29 Alternate menu items. Each item is grouped in one of the four food categories and as in Section 1, the following information is generated for each menu item.

- Item Number
- Item Name (Description)
- Portions Per Cycle
- Portions Per Tray
- Cycles Per Year
- Trays Per Person Per Cycle
- Trays Per Person Per Year
- Overall Item Percentage

All data is generated in the same manner as for the Basic Meal Plan Items. One might note that the parameters Portions Per Cycle and Cycles Per Year have been set equal to 0.0 for the 29 alternate items. This was done to prevent these items from generating a value in the "trays produced per" columns.

3. Item Numbers Presently Not in Use

Item numbers presently not in use

025, 029, 032, 033, 034, 038, 040, 045, 046, 047 052, 054, 055, 056, 057, 061, 066, 075, 077, 080, 082, 083, 086, 087, 088, 089, 090, 091, 092, 093, 094, 095, 096, 097, 098, 099, 100, 101, 102, 104

This section is a listing of just that, the Item Numbers of the 114 in the system, presently not in use.

4. The Ten-Day Basic Meal Plan by Food Categories

TABLE A-3. Ten-Day Basic Meal Plan Items by Food Categories

	Portions per Cycle	Trays per person per Cycle	Trays per person per Year	Overall Annual Percentage
Ten-Day Basic Meal Plan Items				
Entrees	26.0	1.400	51.106	38.892
Starches	13.0	0.590	21.535	16.388
Vegetables	10.0	0.410	14.965	11.388
Fruits and Desserts	27.0	1.200	43.800	33.332
Basic Meal Plan Totals	76.0	3.600	131.406	100.000

This section lists by the Four Food Categories, entrees, starches, vegetables, fruits/desserts, as well as the Basic Meal Plan, the totals for the following :

- Portions Per Cycle
- Trays Per Man Per Cycle
- Trays Per Man Per Year
- Overall Annual Percentage

The above four headings are as defined previously.

5. <u>The Alternate Tray Pack Items by Food Categories</u>

TABLE A-4. Alternate Tray Pack Items

	Portions per Cycle	Trays per person per Cycle	Trays per person per Year	Overall Annual Percentage
Ten-Day Basic Meal Plan Items				
Entrees	16.0	1.101	0.000	0.000
Starches	3.0	0.130	0.000	0.000
Vegetables	5.0	0.200	0.000	0.000
Fruits and Desserts	5.0	0.230	0.000	0.000
Alternate Item Totals	29.0	1.661	0.000	0.000

This section lists by the Four Food Categories, entrees, starches, vegetables, fruits/desserts, as well as the Alternate Tray Pack grouping, the totals for each of the following:

- Portions Per Cycle
- Trays Per Man Per Cycle
- Overall Annual Percentage

B. The Table of Production Demands

This Table is a structured display of the Production Rates required to meet the desired demand which is input interactively or via one of the demand parameters. This table is generated in its entirety for each demand level input. The table can be broken down into five sections as follows:

1. Tray Pack Production Requirements
2. The Ten-Day Basic Meal Plan Items

3. The Ten-Day Basic Meal Plan by Food Categories
4. The Alternate Tray Pack Items
5. The Alternate Tray Pack Items be Food Categories

1. Tray Pack Production Requirements

TABLE A-5. Tray Pack Production Requirements

(based on annual demand)

Number of Trays	Men Fed per Day	Production Days per Year	Production Hours per Day
337,500	2,568	250	8

This section is a Display of the Production Demand and associated constraints. The list of output, regardless of the input demand value. follows:

- Annual Demand in Trays
- Annual Average Number of Men Fed Per Day
- Production Days Per Year Available
- Production Hours Per Day Available

Note that input is either the total number of trays to be produced or the annual average number of men to be fed each day. Since one is a function of the other, both can be given as output by applying the appropriate functional value to the demand input.

Production Days Per Year and Production Hours Per Day are constants and can be set to any desired values for each particular run. Normal settings for these constants are 250 Production Days with 8 Production Hours Per Day.

2. The Ten-Day Basic Meal Plan Items

TABLE A-6. Production Items and Demand Constraints

Ten-Day Basic Meal Plan Items

Item No.	Item Name	Production per Year	Production per Day	Production per Hour	Production per Minute
	Entrees				
002	Beef stew	7,211.23	28.84	3.85	0.06
003	Beef in barbecue sauce	6,249.73	25.00	3.33	0.06
004	Beef pepper steaks	6,249.73	25.00	3.33	0.06
017	Turkey slices w/ gravy	5,208.11	20.83	2.78	0.05
021	Ham slices	5,208.11	20.83	2.78	0.05
028	Frankfurters in brine	4,261.18	17.04	2.27	0.04
035	Meatloaf, mshrm gravy	4,687.30	18.75	2.50	0.04
042	Canadian bacon	15,624.33	62.50	8.33	0.14
058	Beef, ground, creamed	12,499.46	50.00	6.67	0.11
062	Pork sausage links	9,374.60	37.50	5.00	0.08
069	Beef, roast w/ m gravy	4,687.30	18.75	2.50	0.04
071	Breakfast bake	9,374.60	37.50	5.00	0.08
072	Chicken, roast w gravy	6,249.73	25.00	3.33	0.06
073	Eggs,scrambled w/ ham	9,374.60	37.50	5.00	0.08
074	Egg loaf w/ cheddar	9,374.60	37.50	5.00	0.08
105	Chicken ala king	6,249.73	25.00	3.33	0.06
114	Egg loaf w/ mushrooms	9,374.60	37.50	5.00	0.08
	Starches				
023	Scalloped potatoes	3,749.84	15.00	2.00	0.03
026	Beans with pork	3,749.84	15.00	2.00	0.03
044	Macaroni and cheese	7,812.16	31.25	4.17	0.07
064	Potatoes, buttered	7,499.68	30.00	4.00	0.07
067	Noodles, buttered	6,249.73	25.00	3.33	0.06
068	Rice, white	14,999.35	60.00	8.00	0.13
070	Potatoes, sweet, glaze	7,499.68	30.00	4.00	0.07
078	Potato salad	3,749.84	15.00	2.00	0.03
	Vegetables				
022	Three-bean salad	4,687.30	18.75	2.50	0.04
048	Beans, green	7,499.68	30.00	4.00	0.07
049	Peas and mushrooms	7,499.68	30.00	4.00	0.07
059	Corn, whole kernel	7,499.68	30.00	4.00	0.07

060 Carrots sliced	3,749.84	15.00	2.00	0.03
063 Vegetables, mixed	7,499.68	30.00	4.00	0.07
Fruits and Desserts				
010 Cake, orange nut	4,687.30	18.75	2.50	0.04
011 Cake, cherry nut	4,687.30	18.75	2.50	0.04
013 Cake, spice	4,687.30	18.75	2.50	0.04
014 Cake, chocolate	9,374.60	37.50	5.00	0.08
018 Apple sauce	7,499.68	30.00	4.00	0.07
024 Apple dessert	3,749.84	15.00	2.00	0.03
031 Peaches, sliced	11,249.52	45.00	6.00	0.10
039 Pears, sliced	3,749.84	15.00	2.00	0.03
043 Cake, coffee, apple	14,061.90	56.25	7.50	0.12
050 Fruit cocktail	14,999.35	60.00	8.00	0.13
076 Pineapple, diced	7,499.68	30.00	4.00	0.07
081 Pudding, chocolate	7,499.68	30.00	4.00	0.07
113 Cake, blueberry	18,749.19	75.00	10.00	0.17

This section lists the 44 menu items in the Ten-Day Basic Meal Plan. Each item is grouped in one of the four food categories, entrees, starches, vegetables or fruits/desserts. For each menu item, the following information is displayed:

- Item Number
- Item Name (Description)
- Production Per Year
- Production Per Day
- Production Per Hour
- Production Per Minute

Item Number and Item Name are as Natick has defined them.

Production Per Year, Production Per Day, Production Per Hour and Production Per Minute are the production rates in trays of each menu item for the associated time intervals based on the Production Requirements displayed in Table A-5.

3. The Ten-Day Basic Meal Plan by Food Categories

TABLE A-7. Total Production Rates

	Production per Year	Production per Day	Production per Hour	Production per Minute
Ten-Day Basic Meal Plan Items				
Entrees	131,258.92	525.04	70.00	1.167
Starches	55,310.12	221.24	29.50	0.492
Vegetables	38,435.84	153.74	20.50	0.342
Fruits and Desserts	112,495.17	449.98	60.00	1.000
Basic Meal Plan Totals	337,500.06	1350.00	180.00	3.000

The output from the NATPRO below and on the following pages represents a production rate of twenty per minute for all categories of items.

TABLE A-8. Total Production Requirements (20 cpm)

(based on annual demand)

Number of Trays	Men Fed per Day	Production Days per Year	Production Hours per Day
2,250,000	17,122	250	8

APPENDIX B

SIMAN Example

On the following pages is a listing of a SIMAN program and its associated output. The program simulates in a very basic way a "Franks in Brine" production line. This line is just an attempt to show that SIMAN can simulate the Tray Pack production lines presently in existence. The SIMAN programming language will not be discussed in any detail; however it should be mentioned that the language is very English-like and one can get a feeling for what the program will do by just reading the program.

The SIMAN Program For Franks In Brine

```
BEGIN;
        CREATE,12:1,105;
        ASSIGN:A(1)=TNOW;
        QUEUE,1;
        SELECT,SNB:PLACE1:PLACE2:PLACE3;
PLACE1  SEIZE:PACKER1;
        ASSIGN:A(2)=TNOW;
        DELAY:60;
        RELEASE:PACKER1;
        TALLY:1,TNOW-A(2):NEXT(FILL);
PLACE2  SEIZE:PACKER2;
        ASSIGN:A(3)=TNOW;
        DELAY:60;
        RELEASE:PACKER2;
        TALLY:2,TNOW-A(3):NEXT(FILL);
PLACE3  SEIZE:PACKER3;
        ASSIGN:A(4)=TNOW;
        DELAY:60;
        RELEASE:PACKER3;
        TALLY:3,TNOW-A(4);
FILL    TALLY:4,TNOW-A(1);
        QUEUE,2;
        SEIZE:FILLER;
        ASSIGN:A(5)=TNOW;
        DELAY:20;
        RELEASE:FILLER;
        TALLY:5,TNOW-A(5);
        TALLY:6,TNOW-A(1);
        QUEUE,3;
        SEIZE:WEIGHER;
        ASSIGN:A(6)=TNOW;
        DELAY:20;
        RELEASE:WEIGHER;
        TALLY:7,TNOW-A(6);
        TALLY:8,TNOW-A(1);
        QUEUE,4;
        SEIZE:SEAMER;
        ASSIGN:A(7)=TNOW;
        DELAY:20;
        RELEASE:SEAMER;
        TALLY:9,TNOW-A(7);
        TALLY:10,TNOW-A(1);
        QUEUE,5;
        SEIZE:INSPECT;
        ASSIGN:A(8)=TNOW;
        DELAY:20;
```

```
          RELEASE:INSPECT;
          TALLY:11,TNOW-A(8);
          TALLY:12,TNOW-A(1);
          QUEUE,6;
          GROUP:250;
          QUEUE,7;
          SELECT,POR:LOAD1:LOAD2;
LOAD1     SEIZE:RETORT1;
          ASSIGN:A(9)=TNOW;
          DELAY:280;
          RELEASE:RETORT1;
          TALLY:13,TNOW-A(9):NEXT(LEAVE);
LOAD2     SEIZE:RETORT2;
          ASSIGN:A(10)=TNOW;
          DELAY:280;
          RELEASE:RETORT2;
          TALLY:14,TNOW-A(10);
LEAVE     SPLIT;
          TALLY:15,TNOW-A(1);
          QUEUE,8;
          COMBINE:4;
          QUEUE,9;
          SEIZE:BOXER;
          ASSIGN:A(11)=TNOW;
          DELAY:60;
          RELEASE:BOXER;
          TALLY:16,TNOW-A(11);
          TALLY:17,TNOW-A(1);
END;
```

```
BEGIN;
          PROJECT,FRANKFURTER LINE,C.P. LIZAK,7/23/1984;
          DISCRETE,1261,11,9;
          TALLIES:1,PACKER # 1    :
                  2,PACKER # 2    :
                  3,PACKER # 3    :
                  4,PACKERS TIS   :
                  5,BRINE FILLER  :
                  6,FILLER TIS    :
                  7,WEIGHER       :
                  8,WEIGHER TIS   :
                  9,SEAMER        :
                 10,SEAMER TIS    :
                 11,INSPECTOR     :
                 12,INSPECTOR TIS:
                 13,RETORT # 1    :
                 14,RETORT # 2    :
                 15,RETORTS TIS   :
                 16,BOXER         :
                 17,BOXER TIS     ;
          DSTAT:1,NQ(1),QUEUE # 1:
                2,NQ(2),QUEUE # 2:
                3,NQ(3),QUEUE # 3:
                4,NQ(4),QUEUE # 4:
                5,NQ(5),QUEUE # 5:
                6,NQ(6),QUEUE # 6:
                7,NQ(7),QUEUE # 7:
                8,NQ(8),QUEUE # 8:
                9,NQ(9),QUEUE # 9:
                10,NR(1),PACKER # 1:
                11,NR(2),PACKER # 2:
                12,NR(3),PACKER # 3:
                13,NR(4),FILLER    :
                14,NR(5),WEIGHER   :
                15,NR(6),SEAMER    :
                16,NR(7),INSPECTOR :
                17,NR(8),RETORT # 1:
                18,NR(9),RETORT # 2:
                19,NR(10),BOXER    ;
          RESOURCES:1,PACKER1,1:
                    2,PACKER2,1:
                    3,PACKER3,1:
                    4,FILLER,1:
                    5,WEIGHER,1:
                    6,SEAMER,1:
                    7,INSPECT,1:
                    8,RETORT1,1:
                    9,RETORT2,1:
                    10,BOXER,1;
END;
```

Below is the output from the above program as it is listed. The table of "Tally Variables" lists the average time spent by each resource (human or machine) in performing its task. Also listed are the Standard Deviation, Minimum Time Spent, and Maximum Time Spent performing each task. The Number of Observations column is the number of trays passing each resource and having a task performed on it.

The Table of " Discrete Change Variables" lists statistics on the Queues and Resources in the system. For the Queues it measures Average Queue Length, the Standard Deviation of Queue Length, the Minimum Queue Length, the Maximum Queue Length, and the Time Period over which these statistics were gathered. For the Resources, it measures Average Resource Utilization (the percent of time the resource was actually doing work), the Standard Deviation of Resource Utilization, the Minimum and Maximum Percent Utilization of a Resource, and the Time Period over which this Utilization was measured.

The actual output here is fixed, to verify the model is appropriate. In looking in the Number Of Observations column, one can see a very consistent set of numbers. The three Packers each handle 420 trays. This totals to 1260, the same number handled by the Brine Filler, the Weigher, the Seamer, and the Inspector. This would not be the case if SIMAN was used to its fullest extent. When SIMAN is used properly, task times must be assigned randomly and from some predetermined distribution. This in general would cause an unequal number of tasks being performed by each resource, Packers.

One also notices that there are only five Retort observations. This is so since each Retort batch consists of 250 trays. The second Retort has no observations because in this model SIMAN determined only one Retort was needed to process the trays coming through the system. We also see that only 1250 trays and not 1260 trays spent time in the Retorts. This is so since SIMAN determined it was not appropriate to run a batch of 10 trays through

the Retort. Finally one sees that 312 boxes of trays are output by the Boxer, this equates to 1248 trays that could have been generated. If one desires to see just where the 12 missing trays are, SIMAN will determine this and present it in its output.

SIMAN OUTPUT

Table B-1. **TALLY VARIABLES**

SIMAN RUN PROCESSOR RELEASE 1.0 COPYRIGHT BY C. DENNIS PEGDEN

SIMAN SUMMARY REPORT

RUN NUMBER 1 OF 1

PROJECT: FRANKFURTER LINE
ANALYST: C.P. LIZAK
DATE : 7/23/1984

RUN ENDED AT TIME : 0.2912E+05

NUMBER	IDENTIFIER	AVERAGE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS.
1	PACKER # 1	0.6000E+02	0.0000E+00	0.6000E+02	0.6000E+02	420
2	PACKER # 2	0.6000E+02	0.0000E+00	0.6000E+02	0.6000E+02	420
3	PACKER # 3	0.6000E+02	0.0000E+00	0.6000E+02	0.6000E+02	420
4	PACKERS TIS	0.1258E+05	0.7247E+04	0.6000E+02	0.2510E+05	1260
5	BRINE FILLER	0.2000E+02	0.0000E+00	0.2000E+02	0.2000E+02	1260
6	FILLER TIS	0.1262E+05	0.7247E+04	0.8000E+02	0.2516E+05	1260
7	WEIGHER	0.2000E+02	0.0000E+00	0.2000E+02	0.2000E+02	1260
8	WEIGHER TIS	0.1264E+05	0.7247E+04	0.1000E+03	0.2518E+05	1260
9	SEAMER	0.2000E+02	0.0000E+00	0.2000E+02	0.2000E+02	1260
10	SEAMER TIS	0.1266E+05	0.7247E+04	0.1200E+03	0.2520E+05	1260
11	INSPECTOR	0.2000E+02	0.0000E+00	0.2000E+02	0.2000E+02	1260
12	INSPECTOR TIS	0.1268E+05	0.7247E+04	0.1400E+03	0.2522E+05	1260
13	RETORT # 1	0.2800E+03	0.0000E+00	0.2800E+03	0.2800E+03	5
14	RETORT # 2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0
15	RETORTS TIS	0.1535E+05	0.7044E+04	0.5380E+04	0.2532E+05	1250
16	BOXER	0.6000E+02	0.0000E+00	0.6000E+02	0.6000E+02	312
17	BOXER TIS	0.1725E+05	0.7123E+04	0.5460E+04	0.2902E+05	312

Table B-2. **DISCRETE CHANGE VARIABLES**

NUMBER	IDENTIFIER	AVERAGE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME PERIOD
1	QUEUE # 1	0.5416E+03	0.3990E+03	0.0000E+00	0.1254E+04	0.2912E+05
2	QUEUE # 2	0.8654E+00	0.8327E+00	0.0000E+00	0.3000E+01	0.2912E+05
3	QUEUE # 3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2912E+05
4	QUEUE # 4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2912E+05
5	QUEUE # 5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2912E+05
6	QUEUE # 6	0.1082E+03	0.7798E+02	0.0000E+00	0.2500E+03	0.2912E+05
7	QUEUE # 7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2912E+05
8	QUEUE # 8	0.9423E+00	0.9983E+00	0.0000E+00	0.4000E+01	0.2912E+05
9	QUEUE # 9	0.1974E+02	0.2062E+02	0.0000E+00	0.6200E+02	0.2912E+05
10	PACKER # 1	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
11	PACKER # 2	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
12	PACKER # 3	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
13	FILLER	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
14	WEIGHER	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
15	SEAMER	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
16	INSPECTOR	0.8654E+00	0.3413E+00	0.0000E+00	0.1000E+01	0.2912E+05
17	RETORT # 1	0.4808E-01	0.2139E+00	0.0000E+00	0.1000E+01	0.2912E+05
18	RETORT # 2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2912E+05
19	BOXER	0.6429E+00	0.4792E+00	0.0000E+00	0.1000E+01	0.2912E+05